

**WEST AFRICAN CACAO RESEARCH INSTITUTE**

# **ANNUAL REPORT**

**April, 1953 to March, 1954**

**TAFO, GOLD COAST**



ERRATA

Page 10, line 22. For "large" read "larger".  
 \_\_\_\_\_ 30. To read "...olitorius L., C.  
aestuans L.,..."  
 \_\_\_\_\_ 32. For "app." read "spp."

Page 11, Table. Delete full-stops after Burret,  
 Monachino, Stapf, Ridley, Krause,  
 Capuron, these being unabbreviated  
 names.

Page 11, line 11. For "dewerei" read "dewevrei".  
 \_\_\_\_\_ 12. Insert full-stop after "Dur", an  
 \_\_\_\_\_ abbreviated name.  
 \_\_\_\_\_ 14. For "Erothropsis" read "Erythropsis".  
 \_\_\_\_\_ 26. For "oleagine" read "oleagina".

Page 14, line 31. For "predacious" read "predaceous".  
 \_\_\_\_\_ 41. Insert "out" after "carried".

Page 16, line 35. For "gramma" read "gamma".

Page 17, line 2. Insert "and fungicide" after  
 "insecticide".

\_\_\_\_\_ 4. To read "rigidiuscula (Berk. & Br.)  
 Sacc., have..."

\_\_\_\_\_ 13. Insert "punctures" after "feeding".

Page 30, line 40. For "100" read "160".

Page 37, heading of Table IX. For "Established" read  
 "Establishment".

Page 40, heading of second column of Table XIV. For  
 "average" read "acreage".

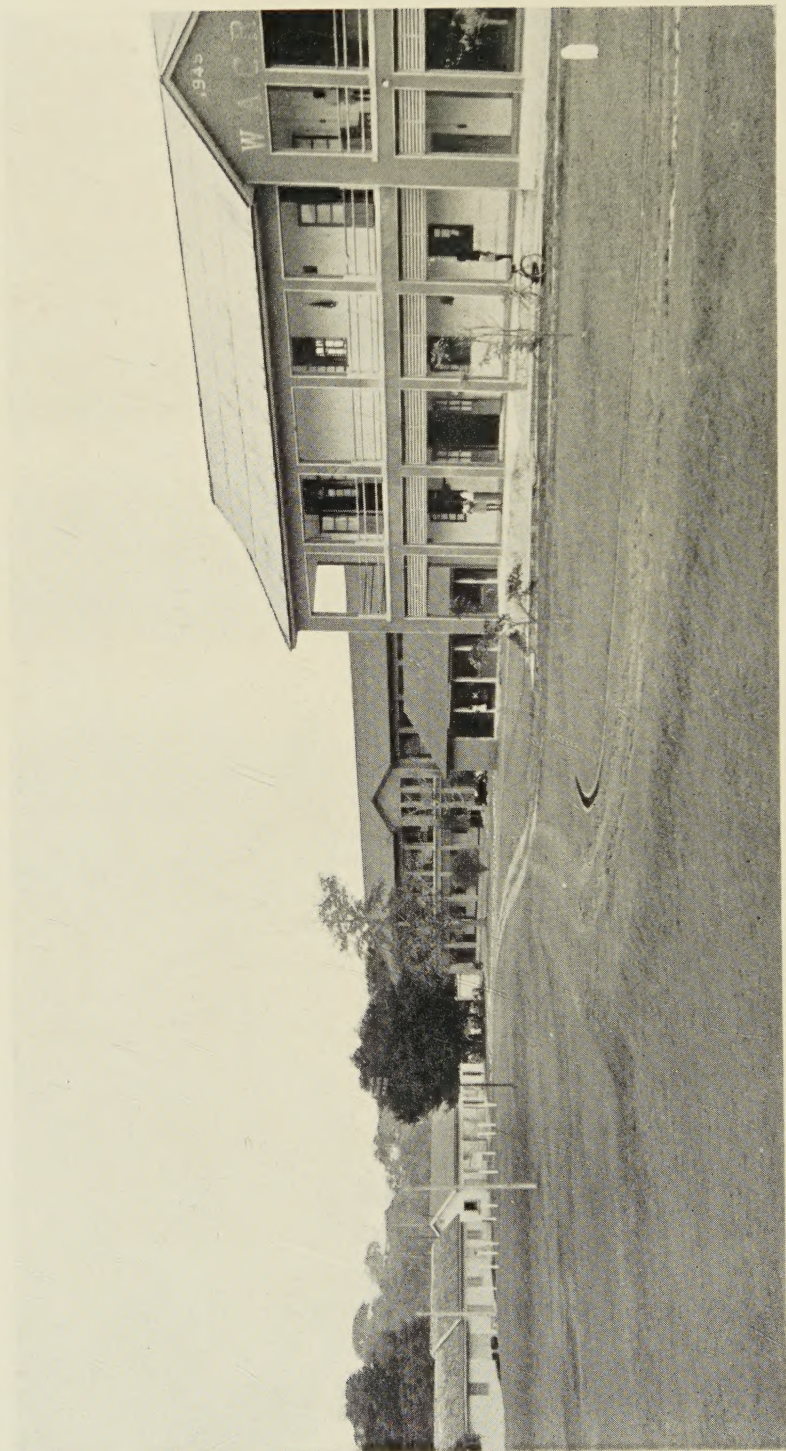
Page 44, rainfall for May, 1953. For "2.25" read "5.2".

Page 49, line 3. For "squirting" read "spray-painting".  
 \_\_\_\_\_ 4. For "Lindane" read "gamma BHC".



Digitized by the Internet Archive  
in 2025





West African Cacao Research Institute, Tafo. Main Buildings.

**WEST AFRICAN CACAO RESEARCH INSTITUTE**

# **ANNUAL REPORT**

**April, 1953 to March, 1954**

**TAFO, GOLD COAST**

Published on behalf of the West African Cacao Research Institute by the  
Crown Agents for Oversea Governments and Administrations,  
4, Millbank, London, S.W.1.

1954

**Price 5/-**

## CONTENTS

---

|                                    | PAGE |
|------------------------------------|------|
| Managing Committee .. .. .         | 3    |
| Staff List .. .. .                 | 4    |
| I. Policy and Organisation .. .. . | 5    |
| II. Virus Research .. .. .         | 8    |
| III. Capsid Research .. .. .       | 14   |
| IV. Soil Science .. .. .           | 17   |
| V. Chemistry .. .. .               | 20   |
| VI. Botany and Physiology .. .. .  | 21   |
| VII. Plant Breeding .. .. .        | 25   |
| VIII. Mycology .. .. .             | 26   |
| IX. Mealybug Studies .. .. .       | 29   |
| X. Agronomy .. .. .                | 33   |

## APPENDICES.

|                                |    |
|--------------------------------|----|
| I. Meteorological data .. .. . | 44 |
| II. Research Programme .. .. . | 47 |



**WEST AFRICAN CACAO RESEARCH INSTITUTE,  
MANAGING COMMITTEE AT 31st MARCH, 1954.**

---

*Chairman.*

A. N. GALSWORTHY, Esq., C.M.G. Chief Secretary, West African  
Inter-Territorial Secretariat.

*Members.*

HONOURABLE NENE AZZU

MATE KOLE. . . . . Konor of Manya Krobo, Gold  
Coast.

R. JOHNS, Esq., O.B.E. . . . . Inspector-General of Agriculture,  
Nigeria.

J. DIXON, Esq. . . . . Principal Assistant Secretary,  
Ministry of Agriculture and  
Natural Resources, Gold Coast.

J. H. ASAFU-ADJAYE, Esq. . . . . Gold Coast.

A. OBISESAN, Esq., O.B.E. . . . . Nigeria.

E. A. SANDA, Esq., O.B.E. . . . . Nigeria.

R. F. A. GREY, Esq., O.B.E. . . . . Development Secretary, Nigeria.

E. W. LEACH, Esq. . . . . Director of Agriculture, Gold  
Coast.

J. WEST, Esq. . . . . Director of Cacao Research.

# WEST AFRICAN CACAO RESEARCH INSTITUTE

SENIOR STAFF LIST AT 31st MARCH, 1954.

---

|                                           |       |                                                                                                                                                                                                                                         |
|-------------------------------------------|-------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Director                                  | .. .. | J. WEST, B.S.A., A.I.C.T.A.                                                                                                                                                                                                             |
| Deputy Director                           | ..    | A. PICKLES, M.Sc., A.I.C.T.A.                                                                                                                                                                                                           |
| Division of Entomology                    |       | J. NICOL, B.Sc.(For.).<br>R. G. DONALD, B.Sc., A.I.C.T.A.<br>H. R. MAPOTHER, B.A., B.Sc., A.R.I.C.<br>P. B. CORNWELL, M.Sc., A.R.C.S.,<br>D.I.C., D.T.A.<br>D. J. TAYLOR, B.Sc., Dip.Agr.Sci.,<br>D.T.A.<br>F. E. DECKER.               |
| Division of Pathology                     |       | W. T. DALE, M.Sc., A.I.C.T.A.<br>T. W. TINSLEY, B.Sc., Ph.D.<br>A. L. WHARTON, B.Sc., Dip.Agr.Sci.,<br>D.T.A.<br>R. M. LISTER, B.Sc., Dip.Agr.Sci.,<br>D.T.A.<br>G. USHER, B.Sc., Dip.Agr.Sci., D.T.A.<br>J. M. THRESH, B.Sc., A.R.C.S. |
| Division of Botany                        | ..    | J. F. ARCHIBALD, B.Sc.(Hort.),<br>F.R.H.S.<br>H. H. ROGERS, B.Sc., Dip.Agr.Sci.<br>R. KNIGHT, B.Sc., Dip.Agr.Sci.<br>A. D. MCKELVIE, B.Sc., Dip.Agr.Sci.,<br>D.T.A.                                                                     |
| Division of Soil Science<br>and Chemistry |       | J. A. R. MACLEAN, B.Sc., Ph.D.<br>S. N. ADAMS, B.A., D.Phil.                                                                                                                                                                            |
| Division of Agronomy                      |       | R. J. BENSTEAD, N.D.A., C.D.A.<br>R. WICKENS, M.A., D.T.A.                                                                                                                                                                              |
| Maintenance Engineer                      | ..    | C. ALDERSON, D.S.O., E.D., B.Sc.,<br>M.Inst.M. and C.E.                                                                                                                                                                                 |
| Station Manager                           | ..    | S. E. N. KWAFO.                                                                                                                                                                                                                         |
| Secretary                                 | .. .. | G. H. NEAL, F.I.A.C., F.R.S.A.,<br>F.C.T.C.                                                                                                                                                                                             |



## I. POLICY AND ORGANISATION.

It is gratifying to record that the senior staff situation has greatly improved and that few vacancies remain without at least a prospective appointee. As a result, it has been possible to meet a long-felt need by opening a sub-station in Nigeria and to post three officers there for the study of problems of particular importance to that country.

It has also been possible to review the Institute's Research Programme in relation to the needs of the cocoa industry of West Africa and it is considered that the long-term programme now adopted bears a close relation to those needs. While many, perhaps most, of the projects will occupy several years for their completion, it is confidently expected that they will also give results of immediate practical importance in the course of their study. Studies such as black pod disease control, capsid control and plant breeding can never be exhaustive, but such studies, if logically pursued, should continually suggest new practical methods of pest and disease control or produce improved planting material.

The Chairman of the Managing Committee, Mr. A. N. Galsworthy, C.M.G., reverts to his substantive appointment at the Colonial Office at the end of the current financial year and Mr. J. West, Director of the Institute, will shortly relinquish his appointment for service elsewhere. Our good wishes go with these gentlemen for their future careers.

### SENIOR STAFF.

There were four additions to the Senior Staff in the course of the year. Mr. W. T. Dale was transferred from the Imperial College of Tropical Agriculture to the post of Principal Plant Pathologist; Messrs. G. Usher and J. M. Thresh were appointed Plant Pathologists and Mr. A. D. McKelvie was appointed Plant Physiologist. Vacancies remain for an Agronomist and for two additional Entomologists; the last two posts represent additions to the establishment recently approved by the Managing Committee. A temporary vacancy for a biochemist also exists; it is proposed to fill this with an officer on secondment.

### MANAGING COMMITTEE.

The Managing Committee met at Tafo on the 12th and 13th November 1953 and on the 9th and 10th March 1954. At the first of these meetings the question of capsid damage to cacao in Nigeria and the Gold Coast received particular attention and it was agreed that there was need for intensified research on this problem. The Committee decided to create an additional post for an entomologist to work on this problem; provision for another entomologist had been made during the preceding year and the establishment of entomologists is thus to be increased by two.

## IBADAN SUB-STATION.

Financial provision was made by the Managing Committee for the erection and equipment of laboratories and bungalows at Ibadan. Four bungalows and a rest house are virtually completed, but work has not yet commenced on the erection of the laboratories. In the meantime temporary use is being made of laboratories under the control of the Research Adviser to the Nigerian Department of Agriculture and the Director's thanks are due to this officer and to the Inspector-General of Agriculture for the facilities afforded. The research adviser also attends to the local administration of the sub-station on behalf of the Director.

Mr. R. G. Donald, Entomologist, had been posted to the sub-station in March 1953. He is undertaking a survey of the mealybugs of cacao in Nigeria, their parasites, predators and ant attendants. On the 16th June 1953, Mr. R. M. Lister was also posted to Ibadan, where he was joined by Mr. J. M. Thresh on the 2nd February 1954. These officers are making special studies of the viruses and virus strains peculiar to Nigeria.

## VISITORS.

Relations with the Departments of Agriculture of the Gold Coast and Nigeria continued to be intimate and many visits were paid to the Institute by officers of these Departments.

The Honourable A. M. Akinloye, Western Regional Minister for Agriculture and Natural Resources, Nigeria, visited the Institute in August 1953.

Two parties of visitors from Nigeria came to the Institute in accordance with the arrangement which has now been in operation for several years. On this occasion, both parties included members of the Western House of Assembly, in addition to teachers and students.

Numerous visits continued to be paid by farmers, teachers and students under the guidance of the Gold Coast Department of Agriculture.

In April 1953, Dr. C. B. Williams of Rothamsted Experimental Station was invited to the Institute to advise in particular on the quantitative work involved in the study of mealybug migration. Thanks are due to him for the valuable help which he rendered. Other visiting scientists included Dr. R. Scott Russell of the University Department of Agriculture, Oxford, and Dr. A. C. Thaysen, Director of the Colonial Microbiological Research Institute, who was accompanied by Dr. W. G. C. Forsyth.



Many visitors associated with cocoa manufacture in the United Kingdom, Holland and Germany also paid visits to the Institute during the year.

#### STATION MANAGEMENT.

During the course of the year, a new Division of Station Management was created and was placed under the control of Mr. S. Ntim-Kwafo. The new division was made responsible immediately for all management duties formerly undertaken by the Agronomy Division and was put in charge of all labour employed by the Institute. The work of the Maintenance Division also is being progressively taken over by the Station Manager. Under the new arrangement, specialist officers are relieved of a good deal of office routine and are thus able to devote themselves more exclusively to research matters. Central control of skilled and unskilled labour has also enabled substantial economies to be effected and duplication of staff by two or more divisions engaged on similar work has been eliminated.

#### LONDON COCOA CONFERENCE.

The Conference organised by the Cocoa, Chocolate and Confectionery Trades Alliance was held in London on the 15th to 17th September 1953. The Institute was represented by the Director and five other members of the Senior Staff, who presented three papers.

#### WEST AFRICAN INTERNATIONAL CACAO RESEARCH CONFERENCE.

A conference of scientists connected with cacao research in various parts of West Africa was held at the Institute on the 12th to 16th December 1953. In addition to the staff of the Institute, some twenty delegates attended, representing Metropolitan France, Liberia, the United Kingdom, Belgian Congo, French Equatorial Africa, French West Africa, Gold Coast, Nigeria, Sao Thome and Sierra Leone.

The Conference was opened by the Gold Coast Minister for Agriculture and Natural Resources, the Honourable A. Caseley-Hayford, who also attended several of the scientific sessions. Twenty-six papers were presented and discussed, twelve of them being prepared by members of the staff of the Institute. This Conference, the first of a series of conferences on agricultural subjects to be held in various parts of West Africa, was considered to be of particular value and interest and to be a major contribution to international co-operation in scientific matters in this part of the world. The Proceedings of the Conference are being prepared for publication.

#### RESEARCH PROGRAMME.

The Institute's research programme has received particular attention in relation to the resources of the Institute and to the



needs of the cocoa industry of West Africa. The programme is necessarily drawn up on a long-term basis, since none of the projects can be completed in the course of a single year. At the same time, it may be confidently expected that results of practical and scientific value will emerge during the course and before the completion of the several investigations.

The programme, as accepted by the Managing Committee, is printed in full at Appendix II.

## II. VIRUS RESEARCH.

### INTRODUCTION.

Information on the characteristics and inter-relationships of its many strains is fundamental to all lines of research on the cacao swollen shoot virus complex. Moreover, although of limited field application under the present policy of control by "cutting-out," this knowledge would become of great practical value should other measures (such as the use of resistant varieties or chemotherapy) become feasible. Some strains display characteristic symptomatology; others do not, but can be separated by other features, of which differential host reactions are the most useful. The phenomenon of cross-protection enables close relationships to be recognized.

The fact that protection is not always absolute, as amongst strains of the New Juaben cacao virus, does not preclude the use of this method for determining relationships, but it does make artificial infection with mild strains, in an attempt to protect them against virulent ones, of very dubious value as a practical control measure.

Investigations on the host ranges of cacao virus strains are yielding information of great interest and practical value. Surveys of natural infection in susceptible West African Tiliales are complementary to laboratory tests. The importance of *Cola chlamydantha* K. Schum. as a potential danger to the cacao in the Western Province of the Gold Coast has been established. The frequency of virus infections in this tree, and the ease with which they can be transmitted to cacao, indicate the desirability of eliminating it, at least from the vicinity of cacao farms.

The control of swollen shoot viruses is made more difficult by the long latent period of the disease, and the occurrence of strains which produce obscure symptoms or pass through symptomless phases. A quick and simple method of diagnosing symptomless infection would be invaluable. The test described later in this report will be useful on a small scale, but is probably unsuitable, in its present form, for use as a practical field measure. Investigations into the chemistry of the reaction may lead to the evolution

of a simpler technique, or enable the test to be used for the diagnosis of infection in a wider range of hosts ; at present it gives reliable results only with *Amelonado* cacao.

The search for new vectors continues ; so far, only mealybugs have been implicated. Studies on the vector relations of the swollen shoot viruses should further elucidate their natural spread, and may lead to improvements in experimental vector transmission techniques.

#### FIELD PROTECTION EXPERIMENTS.

Two field experiments were started in 1947, designed to test the feasibility of protecting cacao trees against virulent strains of the New Juaben virus complex, by infecting them with mild strains. In one, all apparently healthy trees remaining in a plot of the "Rate of Destruction Experiment" (WACRI Annual Reports 1946-47 to 1950-51) were infected by grafting with a mild strain. Both virulent and mild strains were subsequently isolated, the former more readily, from three of these trees which had remained apparently immune to the virulent strain (WACRI Annual Report 1951-52).

Similarly, in the "Field Protection Experiment" (WACRI Annual Reports 1949-50, 1950-51) a mild strain failed to arrest the spread of the virulent one, but did inhibit its symptoms. When the experiment was terminated early in 1953, 77% of the control trees had shown virulent-strain infection ; 17% of the "protected" trees had shown swellings, which are not associated with the mild strain, and from the results obtained in the "Rate of Destruction" plot it can be inferred that others harboured the virulent strain without showing symptoms of it. During the course of the experiment, 20% of the control trees and 5% of the "protected" ones died ; of the survivors, 30% and 16%, respectively, gave no pods in the final year. The yield of the control plots fell to 44% and that of the "protected" ones to 96% of their 1947 pre-treatment yields. The experiment produced no evidence that the mild strain itself caused any yield reduction over a 5-year period.

At first sight these results seem promising, but the fact that "protected" trees may harbour the virulent strain, which can spread from them into other cacao, is a most serious disadvantage. As there is also a risk that the mild strain may itself eventually reduce yields, or even give rise to more virulent strains, "Field Protection" cannot be recommended as a control measure against the New Juaben virus.

#### VIRUS-VECTOR RELATIONS.

Preliminary experiments on this subject were reported by Posnette and Strickland (*Ann. Appl. Biol.*, **35**, p. 53, 1948), who

used the New Juaben strain of the virus and the vectors *Pseudococcus njalensis* Laing. and *Ferrisia virgata* (Ckll). Later, Posnette and Robertson (Ann. Appl. Biol., **37**, p. 363, 1950) described more detailed experiments, mostly concerned with the Mampong strain and *P. njalensis*, although the New Juaben strain received some attention. It is proposed to amplify and check these results.

Using the New Juaben strain and young adults of *P. njalensis*, virus-free vectors were starved for 18 hours, placed on young infected plants for 24 hours and then transferred to dissected beans as test plants, from which they were removed after periods of 2, 4, 8, 16, 32 or 64 hours. Groups of 30 mealybugs from each diseased plant were equally distributed at random amongst the six treatments. Ten infected plants were colonised with vectors in each experiment; but as adequate numbers failed to survive on some, it was not always possible to carry out ten replications.

Combining available results, the two-hour test-feeding time gave a 64% infection rate, but that for the longer periods varied only from 80% to 87%. In one experiment, in which the insects appeared to settle on the test beans quicker than usual, the transmission rate for the two-hour treatment was 80%. Trials have been started using only two mealybugs per test bean to counteract any possible "swamping" effect with large numbers, and the effect of shorter test-feeding periods (7½ min. to 4 hr.) is under investigation.

W. T. DALE.

#### HOST RANGE OF CACAO SWOLLEN SHOOT VIRUS.

An intensive study of the experimental host range of this virus was started in 1951 with the object of testing all available West African species related to *Theobroma cacao* L. In the past year the following species have been found to be susceptible to one or more strains: *Corchorus olitorius* L. *C. aestuans* L. *C. tridens* L. (Tiliaceae); \**Guazuma ulmifolia* Lam., and 3 undetermined \**Herrania* app. (Sterculiaceae). *Bombax sessile* (Benth.) Bakh. (*Pachira oleagina* Decne.) has consistently shown virus-like symptoms after infection, but so far it has not been possible to recover the virus in back-transmission tests to cacao. The plant previously reported (Annual Report, 1950-51) to be susceptible to the New Juaben strain, under the name *Corchorus tridens* L., is now known to have been *C. olitorius* L.

All the species collected for use in these studies were sent to the Herbarium, Royal Botanic Gardens, Kew, for identification. Several new species were represented in the material and many of the names used in previous reports have proved to be invalid. To prevent confusion in the nomenclature of species previously tested, the following list gives the old names together with the new ones.

\* Exotic Species.



KEW DETERMINATIONS OF PLANTS PREVIOUSLY  
TESTED IN THE HOST RANGE EXPERIMENTS.

| OLD NAME                                               | NEW NAME                                                                     |
|--------------------------------------------------------|------------------------------------------------------------------------------|
| TILIACEAE                                              |                                                                              |
| <i>Ledermannia chrysochlamys</i><br>Mildbr. et Burret. | <i>Desplatsia chrysochlamys</i><br>(Mildbr. et Burret) Mildbr.<br>et Burret. |
| <i>Glyphaea laterifolia</i> Hutch. et<br>J. M. Dalz.   | <i>Glyphaea brevis</i> (Spreng.)<br>Monachino.                               |
| <i>Corchorus tridens</i> Linn.                         | <i>Corchorus olitorius</i> Linn.                                             |
| <i>Desplatsia lutea</i> A. Chev.                       | <i>Desplatsia dewerei</i> (De Wild.<br>et Th. Dur) Burret.                   |
| STERCULIACEAE                                          |                                                                              |
| <i>Erythropsis Barteri</i> K. Schum.                   | <i>Erythropsis barteri</i> (Mast.)<br>Ridley.                                |
| <i>Cola cordifolia</i> R. Br.                          | <i>Cola gigantea</i> A. Chev. <i>var.</i><br><i>nov.</i>                     |
| <i>Cola acuminata</i> Schott et Endl.                  | <i>Cola nitida</i> (Vent.) Schott et<br>Endl.                                |
| <i>Cola verticillata</i> Stapf.                        | <i>Cola verticillata</i> (Thonn.) Stapf<br>ex A. Chev.                       |
| <i>Cola togoensis</i> Engl. et Krause.                 | <i>Cola millenii</i> K. Schum.                                               |
| <i>Cistanthera papaverifera</i><br>A. Chev.            | <i>Nesogordonia papaverifera</i><br>(A. Chev.) R. Capuron.                   |
| BOMBACACEAE                                            |                                                                              |
| * <i>Pachira oleagine</i> Deene.                       | <i>Bombax sessile</i> (Benth). Bakh.                                         |

Valuable collections of seed of species in the Tiliales have been received from the University Botanical Gardens in Copenhagen, Denmark. Requests for seed have also been made to Botanical Gardens in Singapore, Ceylon, India and Egypt.

The survey of the distribution of natural infection in *Cola chlamydantha* K. Schum. in the Gold Coast is now complete. The species appears to be confined to the wetter vegetation zones of the Western Province. Virus infections are generally distributed throughout its range, both in forest reserves and in cacao-growing areas. The relationships between the virus strains infecting *C. chlamydantha* and cacao in the Western Province are being investigated.

\* Exotic Species.

The behaviour of several virus strains in selected hosts has been studied intensively during the year, with particular emphasis on susceptibility to infection and rates of virus multiplication. Good evidence of differential susceptibility of some hosts has been obtained. *C. chlamydantha* can be cited as an example. This species is very susceptible to the Bosomuoso strain though quite resistant to the New Juaben strain.

#### STRAINS OF THE VIRUS.

Work on the classification of swollen shoot virus strains has been hampered by a shortage of trained assistants to do the insect transmissions. Grafting techniques have therefore been used instead, which has inevitably retarded progress. From results so far obtained, it is possible to group the viruses occurring within the different geographical areas. Nigeria and the Eastern Province of the Gold Coast each have at least three groups; Ashanti and the Ivory Coast each have at least two. When the results of recent tests are available it may be possible to expand or reduce some of these groups.

T. W. TINSLEY.

#### A CHEMICAL TEST FOR THE DIAGNOSIS OF SWOLLEN SHOOT DISEASE.

Lindner, Kirkpatrick & Weeks (Science, 112, p. 119, 1950) described a chemical method for the diagnosis of viruses in the leaves of stone-fruit trees. This method gave unsatisfactory results with swollen shoot disease. Several modifications were tried, and the following method has been finally adopted:—

10 gm. of undamaged, mature leaves from the tree to be tested are ground up in a mortar with 25 ml. of distilled water. The extract is then squeezed through a piece of muslin and a small part of the expressed juice is heated with an equal volume of normal sodium hydroxide. It is preferable to centrifuge the cooled extract for two minutes. As a control, healthy leaves of the same age and type are similarly treated. Diseased leaves give a red to red-brown colour, and healthy ones a lime-green to greenish-brown colour.

This method has given reliable results with young Amelonado plants infected by a number of Gold Coast and Nigerian strains of the virus, and with mature Amelonado trees infected by several Gold Coast strains.

G. USHER.

#### THE NIGERIAN SUB-STATION ISOLATES OF CACAO SWOLLEN SHOOT VIRUS.

Before the establishment of the Sub-station, the Botanist of the Nigerian Department of Agriculture had made a collection of virus material from various localities in the Western Region,

and this had been grafted on to healthy cacao plants. These, having grown too big, are being replaced by more actively growing seedlings, and further virus isolates are being made from newly reported outbreaks. Recent additions to the collection have included seedlings grafted with infected tissue from Iwo, Agunmu, and three localities in the Ilaro area of mass infection. It is proposed to make detailed observations on a representative selection of isolates, and to carry out cross-protection experiments. Differences in symptom pattern exist between certain of the isolates, and cross-protection experiments at Tafo indicate that they fall into at least three groups.

#### HOST RANGE INVESTIGATIONS.

Using the technique evolved at Tafo, a range of plant species belonging to the order Tiliales are being tested for susceptibility to various isolates, as seed becomes available. Testing has been confined to the Ilesha, Olanla and Offa Igbo isolates, but source plants are being built up so that virus from additional localities can be used in the experiments.

From time to time attempts are made to transmit virus from forest trees growing adjacent to infected cacao. The difficulties of this work have been stressed in previous Annual Reports, and so far the only successful transmissions from a naturally infected Nigerian wild host are those reported from a *Ceiba pentandra* Gaertn. growing near Offa Igbo (Posnette, Robertson and Todd, Ann. appl. Biol., **37**, p. 229, 1950).

#### MEALYBUG VECTORS.

The Sub-station Entomologist is carrying out a survey of mealybugs on cacao in the Western Region and, with his assistance, all species which can be obtained in sufficient quantities are being tested for their ability to transmit swollen shoot. One new vector has been found—*Tylococcus westwoodi* Strickland (det. R. G. Donald), which has transmitted three isolates of the virus in preliminary tests.

#### OBSERVATION PLOTS.

All the trees in an observation plot at Offa Igbo have been tested for virus infection, by grafting material from each one on to seedlings in the insectary. By the end of March, 1954, 27 of the 64 trees on which symptoms have been observed and one of the 232 apparently healthy trees have given proof of infection. The grafted seedlings which have not shown symptoms are still under observation and complete results cannot be expected for some time. With the co-operation of the Cacao Survey Officer, Ibadan, it is hoped that individual yield records can be obtained, at three-weekly intervals, for all trees on the Offa Igbo plot; and for a larger area



of cacao at Koroboto, where the appearance of symptoms is being recorded on a plot of 827 trees, 47 of which had shown infection by the end of February.

R. M. LISTER.

J. M. THRESH.

### III. CAPSID RESEARCH.

#### FIELD STUDIES.

##### *Ecological Studies.*

The ecological studies were commenced in an attempt to elucidate the factors influencing the fluctuations of the capsid populations throughout the year, and the size of the peak population from year to year.

An analysis of the data obtained at the meteorological station at the Institute from August 1944 to July 1948, and an attempt to correlate them with the relative abundance of capsids in the Tafo area, as indicated by the routine collections during the same period, did not prove conclusive. This is probably due to the fact that these meteorological data bear only an indirect relationship to the ecoclimate of the actual habitat of the capsids. Consequently, an examination was started in September of the climatic conditions which exist under the cacao canopy. Two areas were chosen: one in which the canopy was complete and a second in which the canopy was severely degraded by capsid attack. Daily records have been taken to obtain the mean and range of temperature, the relative humidity, and the saturation deficit in each area. The amount of light and the rate of evaporation are also being measured; the former value being obtained by the use of a Marie-Davy actinometer, and the latter with Livingstone porous cup atmometers. At the beginning of March, fortnightly intensive counts of all capsids on one hundred trees in each area were started. Other relevant data including the number of predacious insects, the number of pods, and the amount of flush present are being recorded. These observations will have to continue for at least a year before any conclusions can be drawn.

##### *Population Studies.*

Previous workers have shown that the estimate of the capsid population obtained by Routine Collections bears a close relationship to the actual population. It was decided, therefore, to resume the routine collections in order to serve as a standard with which other methods of estimation could be compared.

The Routine Collections were carried in twelve localities on successive days in the Tafo District. The figures obtained are shown in the following tables.

TABLE I.

|          |    | Number of Capsids per 100 trees and seedlings |                               |
|----------|----|-----------------------------------------------|-------------------------------|
|          |    | <i>Sahlbergella singularis</i>                | <i>Distantiella theobroma</i> |
| October  | .. | 8.7                                           | 13.3                          |
| November | .. | 7.6                                           | 10.6                          |
| December | .. | 7.8                                           | 6.4                           |
| January  | .. | 4.6                                           | 6.1                           |
| February | .. | 2.1                                           | 5.8                           |

TABLE II.

|          |    | Number of Capsids found on pods per 100 pods |                               |                           |
|----------|----|----------------------------------------------|-------------------------------|---------------------------|
|          |    | <i>Sahlbergella singularis</i>               | <i>Distantiella theobroma</i> | No. of pods per 100 trees |
| October  | .. | 2.5                                          | 5.8                           | 222                       |
| November | .. | 2.6                                          | 2.5                           | 164                       |
| December | .. | 3.4                                          | 2.7                           | 103                       |
| January  | .. | 5.6                                          | 8.0                           | 21                        |
| February | .. | 9.3                                          | 13.2                          | 1                         |

Table I refers to the total number of capsids collected per 100 trees and seedlings examined. This gives a reasonable picture of the capsid population. The gradual decrease in the numbers from October supports the general field observation that the peak population occurred much earlier this year than usual. The increase in the number of capsids per hundred pods is largely a reflexion of the virtual absence of pods during January and February, and even a small capsid population on the remaining pods would give a disproportionately high ratio. Two other methods of estimating capsid populations were examined. The first, which was not successful, consisted of a series of experiments in which a sample of the adult population was caught, marked, released and then another sample caught after an interval of a week. This method is based on the principle of the "Lincoln Index", whereby an absolute estimate of the population can be calculated from the ratio of marked specimens to unmarked in the second sample. These experiments were carried out in four areas in the Square Mile during September and October—the months during which the capsid population was at, or near, its peak. No recaptures of marked specimens were obtained. This was attributed to the inaccessibility of that part of the population in the canopy.

The second method was a modification of a technique described by Collyer (Rep. E. Malling Res. Sta. 1949-1950) which utilises the immediate knock-down properties of insecticides containing pyrethrins. An area of forty-eight square yards in a cacao field was completely covered with heavy cotton material and the insecticide was then applied as a fine mist to the canopy. Five stations were treated in a day. The figures obtained using this method during the latter part of November and December compared well with those obtained from the routine counts. However, during January the numbers of capsids obtained were much lower than those from the routine collections.

D. J. TAYLOR.

#### CHEMICAL CONTROL OF CAPSIDS.

##### *DDT dust and cacao pollination.*

Regular dusting at three weekly intervals with 5% DDT dust has had no apparent effect on the pollination of the flowers in this plot. This heavy dusting programme has continued now for two years and the crop which was 3,152 pods last year has increased to 3,507 in the current year.

##### *Chemical control of capsids on intermediate cacao.*

Work has continued on the development of the spray-painting technique for use on cacao which has grown past hand-painting but has not yet grown to a closed canopy suitable for dusting.

A trial carried out at Adonkwanta Sub-station, whilst yielding information on residual effect, is not considered satisfactory due to the smallness of the plots and the poor quality of the only cacao available at that time.

Accordingly a large scale trial has been inaugurated at Nankese Sub-station where reasonably uniform, good quality cacao together with heavy capsid incidence is available.

Five blocks of one thousand trees each have been subjected to the following treatments :

- 1.25% DDT aqueous emulsion.
- 2.5%     "             "             "
- 0.03% gamma-BHC aqueous emulsion.
- 0.06%     "             "             "             "
- untreated control.

Assessment is being made by counting and removing capsid-damaged shoots on all trees and by capsid counts on 10% of the trees according to a statistical layout.

Treatment was first applied in August, 1953, and again in February, 1954, and monthly observations are in progress.

J. NICOL.

H. R. MAPOTHER.



### *Insecticide/Fungicide Trials.*

Field Trials to test the efficacy of combined insecticide sprays in reducing the damage caused by capsids and *Calonectria rigidiuscula*, have been laid down in conjunction with the Division of Plant Pathology. Damage-free seedlings, approximately 18-24 months old, were planted amongst an area of badly damaged seedlings in the Square Mile. The treatments consist of 0.5% DDT emulsion alone, a proprietary fungicide "Perenox", alone, at the rate of 5 lb. per 100 gallons of water, a combined 0.5% DDT and "Perenox" spray, and controls. The treatments were applied when the seedlings were planted, and have been repeated at monthly intervals. The plants have been examined at fortnightly intervals, and the number of feeding and other damage have been recorded. These observations will continue for six months. The fact that very few lesions have been recorded on any of the plants during the past three months is due to the low capsid populations and not to any effect of the treatments, because fresh damage on the surrounding non-experimental seedlings was also very difficult to find.

D. J. TAYLOR.

A. L. WHARTON.

## IV. SOIL SCIENCE.

### CACAO MANURING.

The manuring of a tree crop such as cacao presents two distinct problems, (i) how to manure the seedling to increase vegetative growth and thus to promote early bearing and (ii) how to manure bearing trees to increase or maintain yield. With the object of investigating these problems, a number of field fertilizer trials have been started this year.

#### *The manuring of seedlings.*

Twelve four-acre Amelonado plots were established by the Institute and the Department of Agriculture in the rains of 1953, with the object of providing blocks of uniform material on which experiments could be carried out. The choice of sites was restricted to the cacao stations of the Department of Agriculture but it so happened that fairly representative soils were obtained. Cape Coast granites are represented by sites at Tafo (two plots), Oyoko and Kwadaso; phyllites at Goaso, Poanu, Bechem and Biene; greenstone at Bunso and tertiary sediments at Aiyinasi. At Juaso and Akaa, the plots are on unidentified soils derived from the Tarkwaian and Buem Geological series respectively. On all stations, soils on the tops of undulations were chosen as they are considered most suitable for cacao (1).

In the absence of clonal material, choice of planting material lay between Amelonado and Upper Amazon. The latter, having a much higher potential performance, is more likely to suffer from

nutrient deficiencies and therefore to respond to fertilizers. However, the genetic variability of Amazon is greater than that of Amelonado: the question of what types will be commercially acceptable is still undecided and the supply of planting material was insufficient in 1953 to plant 48 acres of seed at stake. For these reasons Amelonado was chosen for the trials.

In October and November, NPK trials were laid down on all sites except Bechem and Akaa. There were eight treatments designated O, N, P, K, NP, NK, PK and NPK where N, P and K = 2 oz. sulphate of ammonia, superphosphate and muriate of potash respectively. Fertilizer was applied in a circle of one foot radius round the seedlings. Owing to the early onset of the dry season, little growth was made after the fertilizer application and responses cannot be expected until the forthcoming rainy season. At several stations, muriate of potash proved to be markedly toxic, causing leaf-scorch, defoliation and, in severe cases, death of the seedlings. The experiments at Goaso, Poanu and Aiyinasi suffered little or no damage; the reason for this difference is obscure.

To discover if this toxic effect was due to potassium or chloride, a pot experiment was started in which muriate and sulphate of potash were compared. Preliminary results indicate that whilst muriate reproduced the leaf scorch seen in the field, sulphate had no adverse effect. In future, sulphate of potash will be used in all trials.

#### *The manuring of bearing trees.*

The types of phosphate trial described in previous reports has now been abandoned as 70 trees (17% of the experiment) have been removed due to swollen shoot.

Comparison of the 1953-54 with the 1951-52 harvests shows that during the course of the experiment, trees receiving 1 lb. per annum of double superphosphate increased their yield in number of pods by 61% whilst the control yield increased only 23%. As, strictly speaking, the 1951-52 harvest is not a pre-treatment yield, these figures cannot be analysed statistically.

Two conclusions may be drawn from this experiment viz. (i) Long-term field trials cannot safely be carried out in areas heavily infected with swollen shoot even when protected by regular inspection and cutting out. (ii) No results can be obtained from fertilizer trials on peasant cacao without a knowledge of pre-treatment yields.

Analysis of the 1939-46 NPK trial on average cacao at WACRI has, however, shown that experimental error can be reduced to manageable proportions by correcting the yields for pre-treatment yields by analysis of covariance. (2) With the object of getting

a stock of calibrated trees for future field work, 15 peasant farms have been selected and the 1954-5 crop yields will be recorded by the Department of Agriculture. The farms selected are on upland soil types and are reasonably free from capsid damage and remote from swollen shoot outbreaks. Twelve are in Ashanti, two in Togoland and one in the Asikuma area of Western Province. In addition to their value for future field trials, these plots will provide useful information about the performance of peasant Amelonado on different soil types.

Six experiments have been laid down on upper-Amazon plots planted in 1950 by the Department of Agriculture. Four of these are  $2^3$  factorial NPK trials in which sulphate of ammonia, superphosphate and muriate of potash are applied at a rate of one pound per tree per annum. The sites are at Asokore and Jumapo (Cape Coast Granite Soils): Bunso (Greenstone) and Anyinam (Phyllite). Only a few pods reached maturity on these plots in the 1953-4 season but yield records will be taken during the next main crop.

At Nankese, a comparison of different sources of nitrogen has been started using sulphate of ammonia, nitrate of soda and urea. At Kabu Hill, basic slag, superphosphate and triple superphosphate are compared, in a types of phosphate trial.

#### ACKNOWLEDGEMENT.

It is a pleasure to be able to record the most generous assistance and co-operation which has been received from the staff of the Department of Agriculture in all this work.

#### LABORATORY WORK.

Most of the section's time is now occupied with field work. However, a series of experiments to study the effect of nutrition on swollen shoot symptom expression in young Amelonado seedlings, infected with New Juaben strain, is being carried out in conjunction with the Division of Plant Pathology. In a preliminary experiment, young infected Amelonado seedlings were grown in water culture with five replications of the following nutritional treatments: nil, N, P, K, NP, NK, PK, NPK. Transparent vein-banding was most marked in the nitrogen treatments which also appeared to accentuate the "fern-leaf" pattern and significantly reduced the size of root-swellings.

This experiment is being repeated in more detail and, in addition, a water culture experiment to study the effect of symptomatology of different levels of N is in progress.

#### REFERENCES

- (1) CHARTER, C. F. (1947) Cacao Soils Good and Bad.
- (2) WICKENS, R.                      Agronomist, W.A.C.R.I., private communication.

S. N. ADAMS



## V. CHEMISTRY.

### FERMENTATION OF CACAO.

The problem of curing West African Amelonado and Upper Amazon cacao in order to produce a full chocolate flavour on roasting, but without a high proportion of purple beans, is still being studied. The changes in the acid-soluble, polyphenolic compounds in beans from West African Amelonado and some Upper Amazon types during fermentation have been followed, mainly by use of paper chromatography, and results compared with those reported in I.C.S.I. beans by Forsyth (1). The two anthocyanins present have been provisionally identified as cyanidin galactoglucoside (I) and cyanidin arabino-glucose (II) and behave similarly to those from I.C.S.I. beans. Both disappear during a six-day fermentation by any of the methods practised in the Gold Coast (e.g. three-tiered box, basket or ground-heap) or by the laboratory method described by MacLean (2), substance I disappearing by the end of the third, and II by the end of the fifth day.

After sun-drying, many beans remain purple and attempts to isolate and examine this purple residue are in progress. Preliminary experiments on the isolation of the anthocyanins from fresh, unfermented amelonado beans indicate that the purple colour is due to a purple substance or substances in addition to the two anthocyanins mentioned above. It is not known whether this purple fraction is similar to the purple residue remaining after a six-day fermentation and sun-drying or whether the amounts present either before or after fermentation is constant for a given cacao type.

### ASSESSMENT OF FLAVOUR.

It is still considered that samples of fermented and roasted cacao can be satisfactorily assessed for quality using the schedule of quality factors described in a previous Report, or a variant of it, in conjunction with a suitable statistical design.

Details of the present position regarding assessment of flavour and fermentation work at W.A.C.R.I. are given in the paper to the 1953 Cocoa Conference (3).

### ANALYSES OF INSECT SECRETIONS.

An improved procedure for the treatment of the honey-dew from insects feeding on *T. cacao* (stems, petioles and flush leaves usually) has shown that in honey-dew from *P. njalensis* there are at least eighteen freely occurring amino-acids. All are present in the feeding site and no difference in the amino-acid content of the honey-dew from insects feeding on tissue infected by virus 1A or on healthy tissue, was apparent. The eighteen acids include pipercolinic acid, which appears to be much more widespread in nature than was at one time thought.

## CACAO MUCILAGE.

Work on the constitution of the mucilage obtained from cacao stems has been started (in conjunction with the Plant Physiologist). Dried mucilage is obtained by cutting stems into small pieces, immersing them in water at 5°C. overnight and filtering the exudate through glass wool.

Four volumes of ethanol are added to the filtrate, the precipitated mucilage is washed extensively with ethanol and dried in an electric oven at 60°C. The product is a buff-coloured powder which rapidly becomes insoluble in water.

The undried mucilage after precipitation with ethanol can be purified by redispersion in water and reprecipitation either by acidified alcohol or via the copper salt.

Work on the identification and quantitative estimation of the acid hydrolysis products of the dried mucilage is in progress and the effect of (a) autohydrolysis and (b) enzymes on the fresh mucilage is also being studied, the latter with the object of obtaining a method for the removal of mucilage from extractives and sections of fresh cacao tissues where its presence is undesirable.

## HERRANIA OIL.

An encouraging preliminary report on a half-pound sample of this oil, produced by solvent extraction of the oven-dried seeds of *Herrania* sp. "A", has been received from a commercial firm in Great Britain.

The report considers that the oil may be a useful additional source of an edible oil in West Africa, "provided a steady source of supply can be established".

## REFERENCES

1. W. G. C. FORSYTH .. Biochem. J. 51, 511, (1952).
2. J. A. R. MACLEAN .. Nature 166, 910, (1950).
3. J. A. R. MACLEAN .. London Cocoa Conference. Report 1953,  
and R. WICKENS 34.

J. A. R. MACLEAN.

## VI. BOTANY AND PHYSIOLOGY.

### ROUTINE PROPAGATION.

The wooden propagation frames, described previously, have been used during the last rainy season for rooting cuttings in soil on raised nursery beds. Rooting took place in about six weeks: the cuttings were hardened *in situ* and the frame was then removed,

leaving the plants to grow on in the nursery bed until required. On preliminary trials 64% of the cuttings set were rooted and hardened successfully.

#### CLONAL NURSERY.

A total of 42 clone nuclei, each consisting of 24 plants, has been established and more will be planted during the coming rains. Growth has been extremely good and the plants of T.60 planted in May 1952 have met across the rows.

A further two acres of land in Block O of the Square Mile are being prepared for use as a clonal nursery.

#### THE ROLE OF THE LEAF IN THE ROOTING OF SINGLE LEAF CUTTINGS.

As described in the previous report removal of a ring of cortical tissue to the level of the phloem fibres, in the petiole of the leaf of single leaf cuttings, appeared to encourage root production and growth. To test this further and also the rooting behaviour of selections throughout the year, 180 cuttings of each of three selections are set each month. The series of experiments will be completed in May 1954.

#### CULTURE OF CAMBIAL TISSUE IN VITRO.

Work on the culture of cambial tissue of cacao has continued.

Sections of cotyledon tissue have been cultured and have produced abundant cambial tissue from the cut veins. This has been sub-cultured successfully.

#### EMBRYO-GRAFTING AS A METHOD OF TRANSMISSION OF SWOLLEN SHOOT VIRUS.

As reported previously, transmission of *C. SSV* was not obtained with mealybugs from the bark explants used for culture in vitro.

Attempts were made to obtain transmissions by inserting pieces of bark measuring ca. 10 x 2 mm. into the hypocotyl of embryos from which one cotyledon was removed.

Symptoms appeared on a number of the seedlings at either the first or second flush.

Further investigations are being carried out to determine the best method of grafting and the minimum number of grafts necessary to assure a transmission.

#### BIOLOGICAL ASSAY OF GROWTH SUBSTANCES.

Seedlings of a number of species have been tested for suitability as test objects for bio-assay of growth substance, but in all cases extremely variable germination made the use of uniform samples impossible.



It was found, however, that increase of length and weight in cacao embryos detached from the cotyledons was depressed by  $\beta$ -Indole acetic acid. Preliminary experiments showed that sensitivity between pods varied but that there was no variation within pods.

The method has now been refined to the extent that  $5 \times 10^{-8}$  gm. IAA can be detected.

The technique has been used in the experiments on germination where, in under-ripe pods, the testas and adhering pulp contained a substance or substances promoting weight increase, whilst similar material from ripe pods contained a substance or substances depressing weight increase. A substance or substances greatly accelerating weight increase was found in extracts of ovules tested for the Plant Physiologist.

#### GERMINATION OF CACAO BEANS.

During attempts to form a root-fungus association *in vitro*, it was observed that germination of beans under completely sterile condition was greatly delayed compared with that of beans whose testas supported a considerable fungal population.

The observation is being followed up as part of a general investigation of the germination of beans.

#### ASSOCIATION OF FUNGI AND FEEDING ROOTS.

A large number of seedling root systems have been examined for evidence of a fungus-feeding root association. There has been no evidence of any widespread ectotrophic association and on only two occasions have fungal hyphae been found within the root tissues.

J. F. ARCHIBALD.

#### CHERELLE WILT.

##### (i) *Pod Growth Rate.*

Weekly observations on the growth rate of cacao pods in Amazon, Amelonado and Trinitario selections commenced during the year. In all selections the growth rate is similar up to 4 weeks of age.

##### (ii) *Incidence of Wilt.*

Records of wilt incidence are being taken on a large number of trees and attempts are being made to correlate this with environmental factors such as light, soil moisture, etc. Light measurements are being taken throughout the canopy by measuring the rate of the photocatalytic decomposition of oxalic acid in the presence of uranium ions.

##### (iii) *Pod Analysis.*

Pods are being analysed for size and weight, for ovule size and for a large range of nutrients.

(iv) *Growth-substances.*

Efforts have been made to extract growth-substances from cacao ovules. Several extraction methods have been tried and various chemical tests applied but no positive results have been achieved. The extracts are now being tested using biological methods which are more sensitive than the chemical tests. The presence of substances affecting growth has been discovered by this means and work is proceeding in an attempt to identify them.

(v) *Diagnosis of Wilt.*

Daily measurements are at present being made on a number of pods to show whether growth ceases some time before wilting symptoms become visible.

Experiments have commenced to test the effect of flush inhibition on cherelle wilt and also the effect of the application of synthetic growth-substances to pods, but have yielded no results so far.

## Roots.

*Fungus-root associations.*

An experiment has been laid down to test the effect of root-associating fungi on the growth of cacao seedlings. Plants were grown in normal soil in pots and in soil sterilised by heat treatment. Because of an observation made by previous workers that plants with swollen shoot virus have a large number of dead root cells filled with fungal hyphae, a swollen shoot treatment was incorporated in the experiment.

There is little difference in growth rate between plants in sterilised and unsterilised soil, although sterilisation improved germination and early growth.\* The evidence suggests that the virus depresses growth slightly more in the sterilised than in the unsterilised soils.

*Root studies in the field.*

Excavations were carried out during the year on cacao trees growing in different soil types. Water under pressure was used to remove the soil leaving the roots exposed. In all soil types so far excavated there is a fibrous surface root mat which is intermingled with that of other cacao trees. Lateral roots often grow to 15 feet in length and ramify around the base of other trees. The roots are being examined for differences due to soil texture and structure.

*Root studies on seedlings.*

Seedlings are being grown in glass-sided observation boxes and the root system is measured and examined at intervals. It has been shown that a root flush always occurs several days prior to a leaf flush. New root growth is produced, mainly by extensions to the

\* It should be noted that, in this case, the beans themselves were not sterilised.

tap root and existing laterals. The roots of seedlings grow steadily up to about 12 days after germination then further growth is by root flushes. The presence of a root-flush is now being investigated in the field.

#### CACAO MUCILAGE.

Work was carried out on cacao mucilage in conjunction with the Chemist and results are given in the report of the Chemistry and Soil Science Division.

A. D. McKELVIE.

## VII. PLANT BREEDING.

### ESTABLISHED TRIALS.

The maintenance and harvesting of existing trials continued throughout the year. Yields from all seedling trials were lower than in the previous year, but the yield from the two clonal trials increased as a result of more trees coming into bearing during the year.

TABLE III.

Crop for 1953-54 expressed as percentage of 1952/53 crop.

|                  |    |    |    |    |      |
|------------------|----|----|----|----|------|
| Gold Coast Crop  | .. | .. | .. | .. | 86%  |
| 1st P.T.A.       | .. | .. | .. | .. | 88%  |
| 2nd P.T.A.       | .. | .. | .. | .. | 88%  |
| Introductions    | .. | .. | .. | .. | 83%  |
| 1st Clonal Trial | .. | .. | .. | .. | 168% |
| 2nd Clonal Trial | .. | .. | .. | .. | 169% |

### 8TH P.T.A.

A considerable number of the hybrid trees are coming into flower and some are already bearing cherelles in the second year of growth.

The hybrid types WAE, WBE (vide Annual Report 1951-52 p. 27) continue to be more vigorous than the other selections in the trial and a comparison of the stem diameters of 9 selections is shown below in Table IV.

TABLE IV.

8th P.T.A.—Stem Diameter (Cms)—March, 1954

4 Blocks. 9 Selections.

|                |      |      |      |      |      |      |      |      |
|----------------|------|------|------|------|------|------|------|------|
| WA 1           | WA 2 | WB 2 | WB 3 | WE 2 | WE 4 | WBE2 | WBE4 | WAE  |
| 1.84           | 1.95 | 2.04 | 1.57 | 2.21 | 2.42 | 2.61 | 2.30 | 2.57 |
| ( $\pm$ 0.129) |      |      |      |      |      |      |      |      |

Analysis of the data indicates that the West African selections crossed with "Introduced" types are significantly more vigorous ( $P=0.01$ ) than either the amelonado or "local hybrid" selection. The cross WBE2 is significantly more vigorous ( $P=0.05$ ) than the introduced Scavina type.



TABLE V.  
PERFORMANCE OF HIGHEST YIELDING SELECTIONS  
FROM ESTABLISHED TRIALS—1953-54.

| Area         | Selection | Age from<br>planting<br>in field<br>(years) | Diseased<br>pods as<br>% of total<br>pods<br>harvested | Yield from<br>good pods<br>lbs. dry cocoa/<br>Acre<br>(computed) |
|--------------|-----------|---------------------------------------------|--------------------------------------------------------|------------------------------------------------------------------|
| 1st P.T.A.   | E1        | 13                                          | 39·3                                                   | 575                                                              |
|              | N38       | 14                                          | 23·2                                                   | 495                                                              |
|              | A196      | 14                                          | 25·1                                                   | 410                                                              |
| 2nd P.T.A.   | E1        | 12                                          | 21·9                                                   | 695                                                              |
|              | TF1       | 12                                          | 21·7                                                   | 680                                                              |
|              | A72       | 12                                          | 19·7                                                   | 535                                                              |
| 1st Clonal   | ACU 85    | 7                                           | 5·0                                                    | 545                                                              |
|              | A 73      | 7                                           | 5·0                                                    | 535                                                              |
|              | A 12      | 7                                           | 5·0                                                    | 455                                                              |
| 2nd Clonal   | R 15      | 5·5                                         | 17·0                                                   | 335                                                              |
|              | S 21      | 5                                           | 6·2                                                    | 255                                                              |
|              | TF 1      | 5                                           | 4·5                                                    | 200                                                              |
| Introduction | T60       | 9                                           | 13·7                                                   | 1130                                                             |
|              | T76       | 9                                           | 11·4                                                   | 995                                                              |
|              | T79       | 9                                           | 11·5                                                   | 960                                                              |
|              | T85       | 9                                           | 10·6                                                   | 760                                                              |
|              | T72       | 9                                           | 7·7                                                    | 750                                                              |
|              | T63       | 9                                           | 18·3                                                   | 720                                                              |

#### SWOLLEN SHOOT CONTROL.

The increase in the incidence of swollen shoot in the established trial areas has emphasized a need for clone collections in areas relatively free of swollen shoot. All areas are inspected monthly.

#### TREES REMOVED.

| Area                    | Number | Percentage |
|-------------------------|--------|------------|
| 1st P.T.A. .. ..        | 121    | 2·70       |
| 2nd P.T.A. .. ..        | 5      | 0·13       |
| 4th P.T.A. .. ..        | 10     | 2·30       |
| Introductions .. ..     | 6      | 0·32       |
| Clone Collections .. .. | 17     | 0·43       |
| Nursery Extension .. .. | 14     | 0·56       |
| Pollarded Plot .. ..    | 46     | 9·20       |
| Total                   | 219    |            |

## BREEDING PROGRAMME.

The bulk of the hand pollinations have been made to elucidate the incompatibility system in *T. cacao*. The identification of sterility genes is now almost complete for all types of the introduced Amazon population.

The harvesting and despatch of hand-pollinated pods for the one-acre variety trials were completed during the year. The trials are sited at the following Cocoa Stations of the Department of Agriculture, Gold Coast :—

|                  |    |    |         |
|------------------|----|----|---------|
| Eastern Province | .. | .. | Oyoko   |
| ..               | .. | .. | Bunso   |
| Ashanti          | .. | .. | Juaso   |
| ..               | .. | .. | Kwadaso |
| ..               | .. | .. | Bechem  |
| ..               | .. | .. | Poanu   |
| ..               | .. | .. | Goaso   |
| Western Province | .. | .. | Biene   |
| Togoland         | .. | .. | Akaa    |

The site for the 9th P.T.A. has been prepared and the basket seedlings are to be planted in two further variety trials on Department of Agriculture Cocoa Stations.

Land has been made available for Clone Collections at Juaso and Poanu Cocoa Stations. The preparation of cuttings is in progress and the first consignments have been made.

H. H. ROGERS and R. KNIGHT.

## VIII. MYCOLOGY.

## BLACK POD DISEASE.

*Survival of the Causal Fungus during the Dry Season.*

The means of survival of *Phytophthora palmivora* Butl. during the dry season is under investigation. By burying green pods and making isolations from any necrotic tissue developing on them, as described in the previous Annual Report, it has been shown that the fungus can exist as a saprophyte in cacao soils. Six different soil types at W.A.C.R.I. yielded the fungus during the period February to July, 1953.

Survival of the fungus in infected flower cushions is also receiving attention. One thousand trunk cushions, bearing healthy cherelles and pods, were labelled on trees at Bunso Plantation that have been regularly sprayed by the Department of Agriculture with

Carbide-Bordeaux mixture, thereby lessening the chances of pod infection by spores. The condition of the pods on these cushions was observed fortnightly, the cut peduncular surfaces of both ripe and diseased pods being examined for necrosis. Pods with apparently diseased peduncles were borne on 19% of the cushions, indicating that infection was either spreading from cushion to pod, or *vice versa*.

#### MODE OF INFECTION.

Factors for resistance to Black Pod disease may be associated with spore germination and penetration. Diseased pods generally show only one initial point of infection, and it is difficult to produce more than one infection by spraying unwounded pods with a spore suspension. This resistance could be chemical, or due to the closure of stomata, should these be the points of entry for the fungus.

Tannic and chlorogenic acids, extracted from the husks of cacao pods, did not inhibit the growth of *P. palmivora* mycelium on agar medium. It is hoped to test the effect of these and other extracts on spore germination as well as mycelial growth.

The epidermis of cacao pods was successfully removed by boiling in caustic soda. It is hoped to find out if germinating spores enter pods through the stomata, and if so, how far their penetration is hindered by stomatal closure.

#### FUNGICIDAL CONTROL EXPERIMENT.

A four-year factorial spraying experiment has been laid down at Bunso Plantations. It is designed to compare the effect on pod disease incidence and yield of three fungicides: Bordeaux mixture, Carbide-Bordeaux mixture and "Perenox." Comparison will also be made between weekly and three-weekly harvesting, in conjunction with application of the fungicides at different frequencies. Pre-treatment yields and pod disease incidence have been recorded throughout the crop season just ended, and spraying will start in May. During the season, 70% of all pods were damaged by diseases and pests, and 46% were discarded as useless. *P. palmivora* infected 43% and rendered worthless 27% of the total crop.

#### CAPSID-CALONECTRIA CONTROL.

A joint experiment with the Entomology Division, to test the feasibility of reducing damage due to capsids and the fungus *Calonectria rigidiuscula* (Berk. and Br.) Sacc. by a combined insecticidal-fungicidal spray, Carbide-Bordeaux mixture + D.D.T. emulsion, gave results sufficiently encouraging to warrant further investigation.

A. L. WHARTON.



## IX. MEALYBUG STUDIES.

### MIGRATION STUDIES.

#### *The control of Swollen Shoot Disease.*

Investigations into the fate of mealybugs on trees felled and piled during the process of "cutting-out" were completed. The results of preliminary studies of the terrestrial movement of mealybugs from slash piles have been confirmed by the use of insects "labelled" with tracer levels of radio-active phosphorus. Experimental evidence indicates that the process of "cutting-out" is an efficient method of controlling the spread of the cacao swollen shoot virus. Full details of the investigations will shortly be published.

### THE PREVENTION OF SWOLLEN SHOOT DISEASE.

With a view to preventing farmers' cacao from becoming infested by mealybugs and subsequently infected with swollen shoot disease, experiments were designed and are in progress to investigate the effects of cultural practice on vector density. These experiments were also designed to elucidate seasonal fluctuations in mealybug populations and their associated parasites and predators. At the same time, a better understanding of the relationship between vector population and attendant ants will be obtained. Associated with this work, investigations were made into techniques for obtaining radio-active trees for the labelling of insects at their feeding sites in the field. This will assist in studies of canopy and aerial movement of the virus vectors. Experiments conducted during leave in England were successful in producing radio-active trees, but the major difficulties encountered include those of inefficient uptake of radio-active material from the place of introduction into the tree and the localised distribution of radio-activity in the branches.

### ATTENDANT ANTS.

A new method of investigating the species relationships of virus vectors and attendant ants has been made available by radio-tracer techniques. Mealybugs labelled with radio-active phosphorus excrete sufficient levels of radio-activity in their honeydew to radio-activate their attendant ants. This permits the detection of ant trails and nests in the field and affords a measure of the degree of association of species.

P. B. CORNWELL.

### CHEMICAL CONTROL OF MEALYBUGS.

#### *Screening tests and laboratory investigations.*

A few new systemic insecticides were received during the year. Two, which the manufacturers stated to be based on "dimefox" with the addition of activators were tested against pure "dimefox."

Variable results were obtained and, whilst activation was evident, it was by no means constant. With plants growing in sand culture more consistent results were obtained.

### *Field Trials.*

Following a report presented by Messrs. Pest Control Ltd. on a method of implanting the systemic insecticide into holes bored in the trunk at the base of the tree two field scale trials were laid down and carried out jointly by the Institute and the firm's research team. It was hoped that the first would cover the light rainy season and the second the heavy rains. Unfortunately, owing to the vagaries of the weather, the second trial was made during a drier spell than the first.

In the first trial four dosage rates were used 75, 150, 225 and 300 parts per million on the weight of the part of the tree above ground. To investigate the tangential spread of the insecticide two spacings of holes were used viz at 2 inches and 4 inches between centres. The experiment ran for six weeks and at the end all the trees were cut down and the mealybugs on them were counted. An analysis of the results showed that a dose of 260 p.p.m. could be expected to reduce the total mealybug population to about one per tree. If the mealybugs on the pods are excluded from the reckoning, a dose of 160 p.p.m. can be expected to give the same result. These doses are approximately  $\frac{1}{8}$  and  $\frac{1}{3}$  those required for soil application. No difference was apparent when the two-inch or four-inch spacing was used for the holes.

In the second trial 308 trees were used and five levels of dosage 75, 150, 225, 300 and 375 p.p.m. on the tree weight. Holes were drilled at four-inch spacing only and the experiment was designed so that mealybug counts were made on half the trees after six weeks and on the other half after nine weeks. The results of this experiment are being prepared for publication.

### *Effect of the Implantation method on the health of the trees.*

An examination of the stumps of the treated trees showed a heavy dark discolouration around the holes and samples were sent to East Malling for examination. Dead and morbid cells were present and further trials were undertaken to see if repeated applications of the insecticide would have even more profound an effect.

Fifty trees have now been treated five times with an initial dose based on 250 p.p.m. and subsequent doses at 100 p.p.m. The trees were originally drilled and plugged with wooden plugs after treatment but several other methods of plugging to facilitate retreatment have been tried subsequently on some of the trees.

Considerable leaf-fall has been noticed and a joint report will be written by Messrs. Pest Control Ltd. and W.A.C.R.I. when the test finishes.

H. R. MAPOTHER.

J. NICOL.

#### BIOLOGICAL CONTROL OF COCCIDAE.

##### *Natural Enemies.*

A number of species from the collection of local parasites and predators which are new to the W.A.C.R.I. collection have now been determined by the Commonwealth Institute of Entomology.

##### *Introduction of Exotic Parasites.*

During the year eleven species of exotic parasites have been received from the Commonwealth Bureau of Biological Control in California and three species from the substation of the Bureau in Trinidad. Of the latter, two attack *Ferrisia virgata* (Ckll.) and the third (*Hambletonia pseudococcina*) attacks *Pseudococcus brevipes* (Ckll.). The various species have been tested against the indigenous mealybug vectors. *Anagyrus pseudococci*, a new introduction from California, has been reared successfully on *Pseudococcus njalensis*, which it parasitises readily, and on *Pseudococcus citri* and *Pseudococcus brevipes*.

##### *Releases of Imported Mealybug Parasites.*

In all 165,196 parasites involving the following spp. have been released in the five selected areas :—

|                               |          |        |
|-------------------------------|----------|--------|
| <i>Allotropia</i> sp.         | .. .. .  | 19,387 |
| <i>Blepyrus saccharicola</i>  | Gahan .. | 17,825 |
| <i>Leptomastix dactylopii</i> | How.     | 9,010  |
| <i>Pseudaphycus angelicus</i> | ..       | 44,334 |
| <i>Pseudaphycus mundus</i>    | Gahan    | 74,640 |

No recoveries of any of the exotic parasites have been made from the mealybugs collected from the release areas, although 6,350 *P. njalensis* and 108 *P. citri* collected produced 213 indigenous parasites. In order that the small mealybug populations that occur in the field are not disturbed unduly, only very few mealybugs have hitherto been collected at a time but it has been found that inconclusive results have thereby been obtained. It is therefore proposed to discontinue the releases and to collect intensively in the release areas to see if any establishment has taken place.

F. E. DECKER.

#### MEALYBUG SURVEY IN NIGERIA.

Investigations into the relative abundance and distribution of the various species of Pseudococcidae infesting cacao in Nigeria,

and into the complex of natural enemies attacking them, were commenced at the beginning of the year, and have continued since then, except during the period from June to November, when the Entomologist at the Substation was on leave.

### *Mealybug populations and distribution.*

No detailed survey of the mealybug population on cacao in Nigeria will be undertaken until the survey of parasites and predators has passed its preliminary stages. The following observations, however, are of interest in that they indicate comparisons and contrasts between mealybug distribution in the Gold Coast and in Nigeria.

In both territories the numbers of mealybugs found on cacao are in general very small; areas occur with relatively high populations, but these are generally small in extent and are usually surrounded by cacao carrying a more normal low population. However, whereas in the Gold Coast *Pseudococcus njalensis* Laing is the predominant species and areas in which it is replaced by other species are exceedingly rare, in Nigeria two other species, *Planococcus citri* (Risso) and *P. kenyae* (LeP.), may be regarded, in the light of present knowledge, as being of greater importance than *P. njalensis*. Any one of these three species may be found to be the commonest in a given area at any time though at a later date it may be replaced by another. In one area all three have predominated at different times; more commonly one finds *P. kenyae* or *P. citri* predominating with *P. njalensis* very rare indeed, although areas are known in which almost all mealybugs found were *P. njalensis*.

Of the less common cacao mealybugs, *Ferrisiana virgata* (Ckll.) is most frequently encountered, others being *Pseudococcus bukobensis* Laing, *Pseudococcus* sp. nr. *proteae* Hall, *Tylococcus westwoodi* Strickland, *Pseudococcus concavocerarii* James, and *Pseudococcus* sp. nr. *gahani* Green.

There has been little opportunity to examine the mealybugs found at the roots of cacao, but three species have so far been found on one occasion each. Two belong to genera not yet identified, while the third is *Geococcus coffeae* Green.

### *Culturing of Mealybugs.*

Colonies of *P. citri*, *P. kenyae*, *P. bukobensis*, *P. njalensis* and *Pseudococcus* sp. nr. *proteae* have been established, and it is hoped that cultures will be developed for testing these and other species for ability to transmit C.S.S.V.

### *Natural enemies of Cacao mealybugs in Nigeria.*

Sixteen species of Encyrtidae, all of which belong to genera



known to be primary parasites of Pseudococcidae, have been reared from mealybugs collected from cacao. *Leptomastix bifasciatus* Compere is by far the commonest, and is known to attack seven species of mealybug in Nigeria. Over fifty per cent. of all primary parasites so far recorded have been of this species. Others include at least five species of *Anagyrus*, three of *Clausenia* and two of *Tropidophryne*.

Three hyperparasites have been reared, the commonest being *Cheiloneurus carinatus* Comp., which is known to attack *L. bifasciatus*, *Neodiscodes martinii* Comp. and probably *Anagyrus* spp.

Two undetermined Encyrtidae have also been reared, one a male and the other a female; their status and generic placing are not known.

Predators include the larvae of *Cecidomyiidae*, adults of which have been submitted for identification, and both the larvae and adults of the Coccinellidae, *Platynaspis higginsii* Crotch. and nine species of *Scymnus*, including representatives of the subgenera *Scymnus*, *Nephus* and *Pullus*. *Brumus foundrasi* Muls. is known to attack *Antonina graminis* (Mask.) and *Phenacoccus madeiriensis* Green, but has not yet been recorded from any cacao-infesting host. Caterpillars of the Lycaenid moths *Aslaga vininga* Hew. and *Spalgis lemolea* Druce. and of another, unknown Lycaenid, have been found preying on mealybugs. A further unidentified larva has been found in association with ant-attended mealybug colonies, but its relationship with the mealybug is not known.

*Callicaras* sp. has been reared as a parasite of the predaceous *Cecidomyiidae*, and two species of *Homalotylus* from larvae of *Scymnus* spp. *Thysanus* sp. is a hyperparasite of *Scymnus ornatulus* Korsch. through *H. africanus* Timb.

R. G. DONALD.

## X. AGRONOMY.

### TAFO STATION.

#### (a) General.

A series of Transplanting Experiments was laid down, as described in greater detail below. Other new plantings were confined to two acres for establishment demonstration in the "routine planting" sequence and four acres of *Herrania* with a view to producing an adequate sample of beans for future commercial assessment.

Climatic conditions have been favourable for growth and the effect of the abnormally dry spell in November and December (0.78 in.) was less marked than might have been expected.

1,400 seedlings of forest trees were planted throughout the mature cacao of the Old Station to regenerate the overhead shade. There are now seedlings of 48 species in the nursery and an arboretum, which will contain two of each of these and of 23 species under investigation as possible hosts of Swollen Shoot Disease, has been demarcated and prepared for planting in the main rains.

Natural regeneration of indigenous shade trees in the young cacao areas has been most encouraging and it has been possible to cull the less desirable types without a drastic reduction of shade.

(b) *Swollen Shoot Control.*

There has been a slight rise in rate of infection on the Old Station recorded plots, from 1.89% of the current tree population in 1952/3 to 2.04% in the period under review. This represents an increase of less than one tree per acre in an average population of mature cacao trees. On the Square Mile the percentage has risen from 1.25 to 2.08 in the same period.

On the Old Station, retreatment consists of removal of diseased trees and those which are "suspect" whereas on the Square Mile trees in physical contact with symptom bearers are also removed.

Only two seedlings out of 66 acres planted since 1947 have been found to be infected.

(c) *Capsid Control.*

Much of the young cacao has become too tall for hand painting and dusting with 5% D.D.T. and machine spraying has been necessary.

Damage has been particularly severe on widely spaced cacao which has reached the second jorquette stage. All plots of equal age planted at 5' x 5' have maintained a good canopy with little or no damage by capsids.

(d) *Established Cacao.*

The yield of cacao from the recorded plots of the Old Station was 9.4 per cent. lower than that of the previous season, although the total number of pods harvested was 0.8 per cent. greater. This decrease is attributed to a greater loss from pod diseases (11.0

per cent, compared with 5.2 per cent.) and smaller pods (11.7 per lb. compared with 11.2 per lb.).

There was no marked peak as is usual in this area, delivery of crop being fairly regular throughout the major crop season.

TABLE VI.  
DELIVERY OF CROP FROM 63.69 ACRES.

| Date of Picking  | Total Pods |           | % Pods Discarded | Pods fermented | Wet wt. of Beans lb. | Wet wt. of Beans lb. | Pods per lb. dry Cacao | Pods issued out |
|------------------|------------|-----------|------------------|----------------|----------------------|----------------------|------------------------|-----------------|
|                  | Harvested  | Discarded |                  |                |                      |                      |                        |                 |
| 1953             |            |           |                  |                |                      |                      |                        |                 |
| Jun. 22-Jul. 1   | 3,268      | 180       | 5.5              | 871            | 185.7                | 66.62                | 13.1                   | 2,217           |
| Jul. 6-Jul. 20   | 4,334      | 655       | 15.1             | 3,679          | 898.1                | 260.78               | 14.1                   | —               |
| Jul. 27-Aug. 5   | 4,888      | 1,319     | 27.0             | 3,564          | 921.4                | 220.44               | 16.1                   | 15              |
| Aug. 11-Aug. 19  | 7,294      | 3,590     | 49.2             | 3,446          | 979.2                | 210.66               | 16.4                   | 258             |
| Aug. 25-Sept. 1  | 11,750     | 2,502     | 21.3             | 9,208          | 2600.7               | 778.01               | 11.8                   | 40              |
| Total Minor      | 31,534     | 8,246     | 26.1             | 20,758         | 5585.1               | 1536.51              | 13.5                   | 2,530           |
| Sept. 4-Sept. 14 | 21,438     | 2,323     | 10.8             | 18,449         | 4987.7               | 1865.86              | 9.9                    | 666             |
| Sept. 21-Oct. 1  | 51,346     | 4,763     | 9.3              | 46,583         | 11720.9              | 4280.50              | 10.9                   | —               |
| Oct. 6-Oct. 19   | 50,619     | 3,667     | 7.2              | 45,740         | 11189.2              | 4244.10              | 10.8                   | 1,212           |
| Oct. 27-Nov. 12  | 58,395     | 4,669     | 8.0              | 50,070         | 10548.4              | 4668.68              | 10.7                   | 3,656           |
| Nov. 17-Nov. 25  | 25,863     | 3,265     | 12.6             | 8,250          | 1072.4               | 471.70               | 17.5                   | 14,348          |
| Nov. 26-Dec. 7   | 45,198     | 4,288     | 9.5              | 27,470         | 3193.3               | 1805.19              | 15.2                   | 13,440          |
| Dec. 14-Jan. 12  | 96,271     | 10,808    | 11.2             | 83,589         | 14734.0              | 6930.81              | 12.1                   | 1,974           |
| Jan. 19-Jan. 28  | 11,947     | 990       | 8.3              | 7,317          | 1228.6               | 528.86               | 13.8                   | 3,640           |
| Total Main       | 361,177    | 34,773    | 9.6              | 287,468        | 58674.5              | 24795.70             | 11.6                   | 38,936          |
| Grand Total      | 392,711    | 43,019    | 11.0             | 308,226        | 64259.6              | 26332.21             | 11.7                   | 41,466          |

A comparison between the present crop, that of last season and the 16-year mean is given in Table VII.

TABLE VII.

| Season       | Pods Harvested | Percentage pods Discarded | Total Wt. of wet Beans | % Dry to wet wt. | Pods per lb. dry Cacao | Yield per Acre |
|--------------|----------------|---------------------------|------------------------|------------------|------------------------|----------------|
| 1953-4       | 392711         | 11.0                      | 64260                  | 41.0             | 11.7                   | 469.1          |
| 1952-3       | 389752         | 5.2                       | 82341                  | 40.0             | 11.2                   | 517.6          |
| 16-year mean | 545623         | 11.6                      | 100162                 | 41.0             | 11.7                   | 627.5          |

TABLE VIII.

Distribution of Plot yields ( $224 \times \frac{1}{4}$  acre plots).

| Yield Class                           | Percentage of Total number of Plots in each class |         |         |         |         |
|---------------------------------------|---------------------------------------------------|---------|---------|---------|---------|
|                                       | 1949-50                                           | 1950-51 | 1951-52 | 1952-53 | 1953-54 |
| 0— 200                                | 5.80                                              | 4.91    | 4.46    | 5.80    | 11.61   |
| 201— 400                              | 20.09                                             | 20.09   | 13.84   | 28.13   | 30.80   |
| 401— 600                              | 30.36                                             | 34.38   | 25.89   | 29.91   | 30.36   |
| 601— 800                              | 25.00                                             | 22.77   | 30.36   | 23.66   | 17.86   |
| 801—1000                              | 16.07                                             | 12.05   | 16.52   | 10.27   | 8.48    |
| 1001—1200                             | 2.23                                              | 4.46    | 7.14    | 2.23    | 0.89    |
| 1201—1400                             | 0.45                                              | 1.34    | 1.34    | —       | —       |
| 1401—1600                             | —                                                 | —       | 0.45    | —       | —       |
| Highest plot yield<br>in lb. per acre | 1252.84                                           | 1381.32 | 1461.32 | 1103.88 | 1171.84 |
| Lowest plot yield<br>in lb. per acre  | 1.64                                              | 8.64    | —       | —       | —       |

The modal class has fallen from 401-600 to 201-400 lbs. per acre.

The tree population on the 63.69 acres of recorded cacao on the Old Station was reduced by 652, 492 of which were removed during Swollen Shoot Treatment, the balance having died from other causes.

*(e) Field Experiments.*

The experiments reported on in this section are those that are now showing results of practical interest and possible wider application. They are concerned with establishment and spacing of cacao on the land of the Institute and nearby Agricultural Department plots. Full descriptive details are omitted for the sake of brevity and have in any case been given in previous annual and quarterly reports. The remaining experiments which have been noted before are omitted from individual mention on this occasion in order to prevent uninformative repetition and will in future not be reported on unless results of interest accrue or the experiment is terminated.

*First Establishment Experiment.*

A total of 2,310 pods has been harvested from this experiment which was planted in 1947. This number of pods was distributed amongst the various treatments according to the following table which shows the yield in pounds of dry cacao per acre.



TABLE IX.

YIELDS IN FIRST ESTABLISHED EXPERIMENT (1953-4).

| Treatment                                                                                         | Yield in<br>pounds/acre |
|---------------------------------------------------------------------------------------------------|-------------------------|
| 1. Seed at stake, with dry season ring mulching ..                                                | 16.63                   |
| 2. Bare root seedlings with dry season ring<br>mulching .. .. .                                   | 18.03                   |
| 3. Basket seedlings with dry season ring mulching                                                 | 58.75                   |
| 4. Seed at stake in 2' cube holes filled with surface<br>soil with dry season ring mulching .. .. | 11.17                   |
| 5. Seed at stake with small holes as in 2 with<br>dry season ring mulching. .. .. .               | 16.40                   |
| 6. Seed at stake with double quantity of dry<br>season mulch .. .. .                              | 18.62                   |
| 7. Seed at stake without mulching .. ..                                                           | 12.45                   |

No formal analysis of the results has been carried out but attention is drawn to the continued superiority of the basket seedling treatment.

### *Transplanting Experiments.*

The four experiments already in the field at the beginning of the year under review have been described in the previous report (Annual Report WACRI 1952-3 pp. 32-33.).

No further losses beyond those reported in 1953 have occurred in the three experiments planted in 1951. Statistical analyses have been carried out on the percentage losses in the various treatments of the 1952 experiments and Table X shows the mean values obtained. The significance of the fork-lifting versus hand-pulling comparison may be demonstrated and also the interaction of this comparison with leaf removal versus leaf retention. In other words there is a beneficial effect from leaf removal if the plants have been pulled from the nursery bed but a marked reduction in survival if they have been forked out. The optimum treatment is hand forking with leaf retention. This confirms the tentative conclusions recorded in the Annual Report for 1951-2 (p. 43). It is noted from the table that there is no effect of age of seedling in the best handling treatment.

TABLE X.

Mean percentage losses of seedlings after second dry season in field (March 1954).\*

| Treatment at time of transplanting.          | Age of seedlings at time of transplanting in months. |      |      |      |      |
|----------------------------------------------|------------------------------------------------------|------|------|------|------|
|                                              | 8                                                    | 7    | 6    | 5    | 4    |
| Pulled from beds, Leaves not removed .. .. . | 84.5                                                 | 80.6 | 69.5 | 60.7 | 33.5 |
| Pulled from beds, Leaves removed .. .. .     | 34.2                                                 | 40.0 | 43.7 | 49.0 | 43.0 |
| Forked from beds, Leaves not removed .. .. . | 18.0                                                 | 40.0 | 17.7 | 34.4 | 34.9 |
| Forked from beds, Leaves removed .. .. .     | 36.2                                                 | 51.1 | 54.2 | 41.2 | 44.8 |

\*Detransformed angular values.

Three further experiments were planted during April 1953 in co-operation with the Cocoa Agronomy Branch of the Department of Agriculture. In one experiment, planted at Oyoko Cocoa Station, comparisons of percentage losses of seedlings of different ages at the time of transplanting have been made, and at Bunsu and WACRI the further factor of lorry transportation was superimposed on that of age. The accompanying table shows the losses after the first dry season in the field (March 1954).

TABLE XI.

Mean percentage losses of seedlings after first dry season in field (March 1954).

| Site Nursery Beds | Site of field plots | Age of seedlings at time of transplanting in months. |      |      |      |      |
|-------------------|---------------------|------------------------------------------------------|------|------|------|------|
|                   |                     | 8                                                    | 7    | 6    | 5    | 4    |
| Oyoko             | Oyoko               | 24.2                                                 | 17.1 | 16.7 | 10.0 | 18.1 |
| Tafo              | Bunsu               | 36.7                                                 | 23.4 | 18.8 | 14.2 | 9.7  |
| Bunsu             | Bunsu               | 27.0                                                 | 15.7 | 8.8  | 9.8  | 5.9  |
| Bunsu             | Tafo                | 25.1                                                 | 13.5 | 9.7  | 11.9 | 6.2  |
| Tafo              | Tafo                | 20.3                                                 | 19.9 | 18.2 | 9.3  | 10.0 |
| Mean—All sites    |                     | 26.7                                                 | 17.9 | 14.4 | 11.0 | 10.0 |

The age of seedling factor is here showing a significant effect in that the younger seedlings are superior, although those at Oyoko do not conform to the general pattern. However final recommendations must await the survival figures after two dry seasons in the field. The low percentage loss figures for the 5 and 4 month-old seedlings compare favourably with those obtained in similar circumstances in the 1951 experiment (Annual Report WACRI 1951-2 Table 26 p. 44) where losses at two sites of four-month old seedlings after one dry season in the field were of the order of 10%.

#### UPPER AMAZON SPACING AND PRUNING EXPERIMENT.

The yields of cacao from this experiment have been analysed and the table below shows these in terms of pods per tree, and pounds of dry cacao per acre.

TABLE XII.

Yields from Upper Amazon Spacing Experiment (1953-4).

| Spacing               | 8' × 8'    | 10' × 10'  | 12' × 12'  |
|-----------------------|------------|------------|------------|
| <i>Unpruned plots</i> |            |            |            |
| Pods per tree .. ..   | 4.33       | 7.40       | 4.37       |
| Dry cacao per acre .. | 264.5 lbs. | 287.9 lbs. | 182.3 lbs. |
| <i>Pruned plots</i>   |            |            |            |
| Pods per tree .. ..   | 5.06       | 5.52       | 9.12       |
| Dry cacao per acre .. | 310.4 lbs. | 216.8 lbs. | 247.4 lbs. |

Statistical analyses of the yields have been carried out, and demonstrate no significant differences in the number of pods per tree, but they do show the significant superiority of the pruned plots, in terms of dry cocoa per acre, at the widest spacing and, within the pruned plots themselves, the significant superiority of 8' × 8' spacing as compared with 10' × 10', and overall a significantly greater yield in the 8' × 8' plots when compared with the 10' × 10' and 12' × 12'.

In terms of cacao per acre the beneficial effect of close spacing is perhaps not unexpected at this stage of limited plant competition.

R. J. BENSTEAD and R. WICKENS.

#### SUBSTATIONS.

The capsid control problem remains acute particularly in areas of widely spaced cacao. Growth has been good on all established areas but the patches where food crops had been grown prior to the cacao planting are still in evidence after eight years.

The incidence of Swollen Shoot Disease remains low at all substations and is proportionate to the quantity and proximity of infective material on the boundaries.

At Nankese where other cacao has been killed out there has been no infection for six years. Infection would appear to have been eradicated at Koransang, where the young cacao was established concurrently with "cutting out."

TABLE XIII.

Swollen Shoot—Substations.

| Substation | Number | Remarks                                        |
|------------|--------|------------------------------------------------|
| Akwadum    | 29     | 23 found in A43, one in A23 and five in R.T.A. |
| Nankese    | —      | —                                              |
| Koransang  | —      | —                                              |
| Kukua      | 16     | Four in plot A and 12 in plot B.               |
| Adonkwanta | 19     | 13 in plot A and six in plot B.                |

Yields from the more advanced areas of Koransang, Kukua and Nankese are shown in Table XIV.

TABLE XIV.

Yields on Selected Areas.

| Substation | Average | Yield Pods |        | Estimated yield lbs. dry per acre cacao |        |
|------------|---------|------------|--------|-----------------------------------------|--------|
|            |         | 1953-4     | 1952-3 | 1953-4                                  | 1952-3 |
| Koransang  | 3.0     | 8,197      | 3,810  | 228                                     | 106    |
| Kukua      | 5.0     | 24,745     | 7,385  | 412                                     | 123    |
| Nankese    | 3.5     | 8,331      | 3,621  | 197                                     | 86     |

Adonkwanta substation remains backward in coming into bearing and drastic shade removal has been carried out during the year.

R. J. BENSTEAD.



## CACAO FERMENTATION AND QUALITY.

### *Upper Amazon and Related Cacaos.*

Reference to the Annual Report for 1951/2 (p. 49) will recall that a large number of replicated small samples of Upper Amazon and related cacaos were submitted to the B.F.M.I.R.A., General Foods Corporation and local taste panels for flavour assessment. Reports have now been received from all panels and an attempt has been made to collate these results and also to compare them with those from assessments during previous years. It appears that selections are beginning to fall into place with respect to flavour in so far as T60, T63 and T79 appear consistently superior and T12 and T76 appear consistently inferior.

The chocolate industry have repeatedly asked for bulk samples of new selections and during the 1952-3 crop year approximately two hundred-weights of various Amazon cacaos were prepared and submitted after thorough mixing, as four bulk samples of 55 lbs. each. The only report available on these samples is that contained in the Report of the London Cacao Conference, 1953 (p. 70) where Wadsworth states: "For the first time the quantity was such that it was possible to process the beans on factory plant. The Cocoa Scientific Advisory Committee (of the B.F.M.I.R.A.) found that this sample was within the West African flavour range, although it was harsher than a really good West African cacao."

This statement is of further interest in that 55.9% of the total pods making up that 2 cwt. bulk were of the types falling into the higher flavour groups when all small scale assessments were considered, as described in the first paragraph of this section.

Accordingly, during the crop year under review basket fermentations of bulked parentage groups of Amazon cacaos have been carried out together with parallel fermentations of West African Amelonado derived from Bunso and WACRI whence came the bulk of the "1.3" generation Amazon material. (In passing it should be recalled that up to 1952/3 crop year all samples submitted for flavour assessment were from the "Trinidad Introductions Area" but subsequent to that year the material has been derived from the next generation extension plots, popularly referred to as "F3."). The selection T76 is the only one in the Parinari  $\times$  Nanay and Nanay  $\times$  Parinari parentage group which falls in the inferior flavour classification, consequently this parentage group has been divided into lots with more than and less than ten per cent of T76 in their make-up. Collection of samples during the current crop year has resulted in the distribution of bulk lots as in the accompanying table.

TABLE XV.

Showing quantities of cacao for assessment by expert panels (1954).

| Parentage Group                                                               | Submitted to<br>B.F.M.I.R.A.<br>panel | Awaiting sub-<br>mission to<br>G.F.C. panels |
|-------------------------------------------------------------------------------|---------------------------------------|----------------------------------------------|
| Parinari × Nanay and Nanay ×<br>Parinari (with more than 10 %<br>T76) .. .. . | 250 lbs.                              | —                                            |
| Parinari × Nanay and Nanay ×<br>Parinari (with less than 10 %<br>T76) .. .. . | 600 lbs.                              | 600 lbs.                                     |
| Scavina .. .. .                                                               | 280 lbs.                              | 280 lbs.                                     |
| Nanay × Iquitos and Iquitos ×<br>Nanay .. .. .                                | 300 lbs.                              | 300 lbs.                                     |
| Nanay .. .. .                                                                 | 250 lbs.                              | —                                            |
| Iquitos × Parinari .. .. .                                                    | 90 lbs.                               | —                                            |
| W.A.A. (as control) .. .. .                                                   | 375 lbs.                              | 375 lbs.                                     |

## FERMENTATION EXPERIMENTS.

No major experiments have been embarked on during the year but as a result of the generous assistance of the Statistics Department of Rothamsted Experimental Station it has been possible to summarise the results of the Basket Fermentation experiments carried out with the co-operation of the Department of Agriculture in the 1951/2 crop year.

It will be recalled that these experiments, carried out on a country-wide scale extending from Tafo in the Eastern Province to Bechem in Ashanti and including two British Togoland stations, were designed to examine the effect of degree of ripeness of the pods and length of pod storage time on the quality of West African Amelonado cacao over a range of conditions. (Annual Report, WACRI 1951/2 pp. 48-9). The quality of the cacao has been judged in this instance by the percentage purple beans occurring in a cut test performed within fourteen weeks of fermentation and drying. Statistical analysis of the percentages of purple beans confirms the hypothesis that increased ripeness of cacao is an important factor in reducing the proportion of purple beans in the cured product and indicates that the "pod storage" factor is far less definite in its effects.

## CURED CACAO STORAGE EXPERIMENTS.

In a preliminary experiment in 1951/2 it was shown that the purple bean content of Amelonado cacao dropped from 79% when

examined on November 1st to 20.5%, when examined on June 30th 1952. This cacao was stored in a bag in a conventional office building which was fully ventilated by day and closed at night. Other samples stored on cacao drying trays showed parallel changes, as did some mixed Amelonado and Upper Amazon cacao. After the purple bean percentage had reached this level there was no evidence of a further drop, and observations ceased on August 11th 1952.

It was decided to follow up this observation during the 1952/3 crop-year when a total of 115 Amelonado and 19 Upper Amazon samples each of 4 lbs. weight were kept in a small ventilated store for periods up to 48 weeks. Purple bean counts were made at eight weekly intervals.

An extract of the accumulated data is shown below. The figures are classified according to month of harvest (with two lots for each month) and according to time of sampling (8, 16 to 48 weeks).

TABLE XVI.  
Showing percentage purple beans.

| Month of<br>Harvest<br>(1952)     | Sample<br>No. | Storage time in Weeks |      |      |      |      |      |
|-----------------------------------|---------------|-----------------------|------|------|------|------|------|
|                                   |               | 8                     | 16   | 24   | 32   | 40   | 48   |
| August ..                         | 1             | 41.3                  | 62.3 | 41.0 | 35.3 | 30.3 | 26.7 |
|                                   | 2             | 58.7                  | 60.0 | 51.3 | 42.0 | 35.0 | 31.3 |
| September ..                      | 1             | 70.0                  | 71.3 | 58.7 | 49.0 | 41.3 | 39.0 |
|                                   | 2             | 73.3                  | 68.0 | 66.3 | 60.7 | 52.3 | 44.0 |
| October ..                        | 1             | 51.0                  | 70.0 | 49.3 | 38.7 | 32.0 | 29.3 |
|                                   | 2             | 54.7                  | 58.0 | 48.7 | 41.3 | 37.7 | 32.7 |
| November ..                       | 1             | 52.7                  | 26.7 | 22.0 | 21.3 | 19.0 | 18.0 |
|                                   | 2             | 66.0                  | 48.3 | 39.7 | 39.3 | 33.0 | 30.0 |
| December ..                       | 1             | 60.7                  | 46.7 | 37.7 | 30.3 | 27.7 | 24.7 |
|                                   | 2             | 57.3                  | 53.0 | 40.7 | 36.8 | 31.3 | 30.3 |
| Average values<br>over all months |               | 58.6                  | 56.4 | 45.5 | 39.5 | 34.0 | 30.6 |

A statistical analysis of this data shows that the purple bean percentage is significantly reduced with increasing storage time and it may be expected that the purple bean percentage of Amelonado cacao will be reduced at the approximate rate of 3% for every four weeks of storage.

The results of the preliminary experiment (1951/2) had indicated that there was a falling off in the decrease after the percentage had reached 20%-30%, and a more extensive examination of the recent data will be necessary to determine the true form of the relationship, which may well show a "diminishing-return" form instead of the proportionate fall indicated by this statistical analysis.

R. WICKENS.

APPENDIX I.  
METEOROLOGICAL DATA—A: TAFO STATION  
FIGURES FOR 1953 COMPARED WITH 16-YEAR MEANS

|                                     | Jan  | Feb  | March | April | May  | June  | July | Aug  | Sept | Oct  | Nov  | Dec  |
|-------------------------------------|------|------|-------|-------|------|-------|------|------|------|------|------|------|
| Highest Shade Maximum 16-Year Mean  | 91.4 | 93.8 | 93.4  | 93.8  | 92.3 | 89.3  | 87.0 | 86.3 | 88.1 | 89.8 | 90.6 | 90.7 |
| " " " 1953                          | 91   | 95   | 93    | 95    | 95   | 89    | 89   | 85   | 89   | 89   | 92   | 92   |
| Lowest Shade Minimum 16-Year Mean   | 59.4 | 61.4 | 65.8  | 66.1  | 66.7 | 66.1  | 66.1 | 65.1 | 66.7 | 66.7 | 65.3 | 62.5 |
| " " " 1953                          | 65   | 64   | 65    | 66    | 68   | 65    | 63   | 67   | 67   | 73   | 69   | 59   |
| Mean Relative Humidity 16-Year Mean | 86.1 | 83.8 | 81.8  | 80.6  | 81.6 | 84.8  | 86.1 | 86.1 | 85.3 | 83.3 | 81.6 | 84.0 |
| " " " (9.00 GMT) 1953               | 87.6 | 84.6 | 84.3  | 82.7  | 81.2 | 86.0  | 88.4 | 88.2 | 88.7 | 85.1 | 78.8 | 80.9 |
| Mean Relative Humidity 16-Year Mean | 54.7 | 51.9 | 55.1  | 58.1  | 62.6 | 68.6  | 69.4 | 68.7 | 71.0 | 70.8 | 65.1 | 61.1 |
| " " " (15.00 GMT) 1953              | 63.0 | 60.2 | 61.3  | 60.5  | 67.9 | 78.0  | 76.2 | 80.9 | 77.1 | 85.0 | 61.1 | 56.1 |
| Rainfall in inches 16-Year Mean     | 1.56 | 3.66 | 6.01  | 5.72  | 6.96 | 8.45  | 5.67 | 2.72 | 6.13 | 8.72 | 4.79 | 2.31 |
| " " " 1953                          | 1.48 | 4.11 | 4.78  | 3.48  | 2.25 | 10.08 | 7.73 | 1.66 | 4.64 | 9.89 | 0.43 | 0.35 |
| Number of Wet days 16-Year Mean     | 3.4  | 7.1  | 11.7  | 11.1  | 13.4 | 18.3  | 13.6 | 12.8 | 14.1 | 17.9 | 10.6 | 5.9  |
| " " " 1953                          | 3    | 4    | 13    | 10    | 14   | 16    | 16   | 12   | 16   | 17   | 4    | 4    |

ANNUAL RAINFALL FIGURES 1938-1953, IN INCHES

|       | 1938  | 1939  | 1940  | 1941  | 1942  | 1943  | 1944  | 1945  | 1946  | 1947  | 1948  | 1949  | 1950  | 1951  | 1952  | 1953  | 16-Year Mean |
|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|--------------|
| 55.33 | 84.96 | 56.92 | 56.59 | 59.45 | 69.09 | 49.12 | 68.87 | 47.03 | 67.30 | 66.99 | 71.81 | 63.47 | 66.23 | 65.77 | 53.88 | 62.68 |              |



B.—SUBSTATIONS  
RAINFALL IN INCHES—1953

| STATION           | Jan  | Feb  | Mar  | April | May  | June  | July | Aug  | Sept | Oct   | Nov  | Dec  | Total |
|-------------------|------|------|------|-------|------|-------|------|------|------|-------|------|------|-------|
| Akwadum ... ..    | 0.22 | 2.70 | 6.41 | 4.14  | 5.46 | 5.74  | 4.60 | 1.18 | 5.81 | 10.11 | 1.92 | 0.71 | 49.00 |
| Nankese ... ..    | .36  | 1.02 | 8.08 | 4.80  | 6.61 | 1.75  | 4.11 | 1.08 | 5.18 | 8.13  | 3.24 | 0.82 | 45.18 |
| Koransang ... ..  |      | 1.60 | 6.71 | 3.29  | 8.47 | 8.16  | 3.62 | 1.42 | 4.45 | 9.47  | .85  | 1.30 | 49.34 |
| Kukua ... ..      |      | 1.20 | 6.92 | 1.73  | 9.31 | 10.27 | 1.91 | 0.45 | 5.51 | 8.66  | —    | 1.95 | 47.91 |
| Adonkwanta ... .. | 1.28 | 7.59 | 7.88 | 7.32  | 6.35 | 6.87  | 2.49 | 0.96 | 6.85 | 8.08  | 0.16 | 0.41 | 56.21 |

ANNUAL RAINFALL COMPARED WITH PREVIOUS YEARS

| Year | Akwadum | Nankese | Koransang | Kukua | Adonkwanta |
|------|---------|---------|-----------|-------|------------|
| 1950 | 47.80   | 57.01   | 48.21     | 42.08 | 60.79      |
| 1951 | 78.82   | 59.66   | 73.20     | 60.67 | 69.40      |
| 1952 | 56.44   | 57.95   | 60.28     | 51.37 | 76.01      |
| 1953 | 49.00   | 45.18   | 49.34     | 47.91 | 56.21      |

MONTHLY RAINFALL (IN INCHES) AND NUMBER OF WET DAYS—  
APRIL, 1953—MARCH, 1954

| Month                     | April | May  | June  | July | Aug  | Sept | Oct  | Nov  | Dec  | Jan  | Feb  | March |
|---------------------------|-------|------|-------|------|------|------|------|------|------|------|------|-------|
| Rainfall in inches ... .. | 3.48  | 5.25 | 10.08 | 7.73 | 1.66 | 4.64 | 9.89 | 0.43 | 0.35 | 2.77 | 5.40 | 5.31  |
| Number of Wet Days ... .. | 10    | 14   | 16    | 16   | 12   | 16   | 17   | 4    | 4    | 7    | 8    | 9     |

## APPENDIX II.

## 1. VIRUS RESEARCH.

(a) Elucidation of the host range of the swollen shoot viruses and virus strains of cacao in the Gold Coast and Nigeria. The object is to assess the importance of the natural flora in virus spread and involves testing arboreal, shrubby and herbaceous components of the flora accompanying cacao for natural virus infection and susceptibility to artificial infection.

(b) Recognition of the optimum conditions for transmission of swollen shoot virus by mealybugs and their relation to virus spread in the field. This includes study of the influence of the duration of the infection feed, of the test feeding time, the effect of pre-infection starving periods, the effect of varying numbers of vectors, of the age of the vectors and the relative efficiency of different vector species ; search for other vectors.

(c) Classification of the viruses and virus strains affecting cacao in West Africa. This involves study of ; cross-protection phenomena, details of symptom expression, differential hosts and vectors, rate of virus multiplication in different hosts and the possible serological reactions of cacao viruses.

(d) Techniques for mechanical transmission of swollen shoot virus : involving the removal of tannins, mucilage and other ingredients from host extracts ; purification of virus extract ; effect of various ingredients of cacao extracts on the infectivity of other viruses.

(e) Effect of host plant nutrition on susceptibility to infection, on symptom expression and on rate of virus multiplication. Plants grown in varying nutrient cultures are the object of study in the first instance. The studies will be extended to field experiments according to the results obtained.

(f) Chemical detection of virus infection. Recent work has shown that the presence of virus can be detected from the colour change which occurs in leaf extract after suitable chemical treatment and that infection can be detected prior to the development of symptoms. The method is to be refined and its full potentialities explored.

(g) Morbid histology of virus-infected cocoa. This involves a detailed study of the changes in the tissues of the cacao tree which result from virus infection, from the time of infection to the death of the tree.

(h) Studies of cacao virus in tissue cultures *in vitro* : study of (i) methods of virus transmission from cultures ; (ii) survival of virus in cultures ; (iii) effect of nutrition on persistence of virus ; (iv) virus inhibitors.

(i) Virus transmission by embryo grafting ; transmission from wild hosts ; distribution of virus in different organs and tissues of the host plant.

## 2. MEALYBUG STUDIES.

(a) Movement of mealybugs in and between standing trees. The extent to which mealybugs move and are moved from tree to tree, their rate and direction of movement and the factors affecting such movement are at present obscure. This problem, however, of paramount importance in relation to the spread of swollen shoot disease and will be studied using radio-active tracer techniques amongst others.

(b) Effect of wind currents on mealybug dispersal. It has already been shown that mealybugs are often carried by the wind. The practical importance of this type of dispersal is to be examined, together with the conditions in which it occurs. The study is of particular interest and importance in connection with the discontinuous spread of swollen shoot disease ("jump spread").

(c) Study of the seasonal variation in mealybug populations in different types of habitat, including study of the factors leading to the development of exceptionally large mealybug populations.

(d) Biological control of mealybugs. Releases of imported parasites are to be continued in the Gold Coast and will be extended to Nigeria if and when circumstances warrant this. Investigation of the possible establishment of introduced parasites in the Gold Coast is to be intensified. A survey of the indigenous parasites of mealybugs of cacao in Nigeria is to be undertaken, to be followed by investigation of the mealybugs concerned and their ant attendants.

(e) Chemistry of mealybugs secretions. An attempt to explain relative attractiveness of different mealybug species of different species of attendant ants.

(f) Systemic insecticides for mealybug control. See paragraph 12 (b), Insecticide Studies.

## 3. STUDIES OF BLACK POD DISEASE.

(a) Spraying and dusting trials for the control of black pod disease. Two major experiments will be conducted: the spraying trial will compare the effect of "Perenox", Carbide-Bordeaux, Bordeaux Mixture and no treatment: dusting trial will compare the effect of a fungicidal dust with no treatment. The experimental plant provides for three frequencies of application in the first year, to be reduced in subsequent years and for comparison of the effect of harvesting at weekly and three-weekly intervals.

(b) Investigation of the methods of spore dispersal; study of air dispersal and soil infection; dry season phase of the fungus.

(c) Study of cushion infection and its relative importance in the production of diseased pods.

(d) Chemistry and commercial utilisation of beans from diseased pods.

## 4. CAPSID STUDIES.

(a) Further investigation of the regeneration of areas seriously



damaged by capsids by coppicing, with special reference to the protection of new growth by residual insecticides.

(b) Trial of a " squirting " method for the protection of young bearing trees with DDT and Lindane.

(c) Comparative trial of dusts and wet mists for capsid control on fully mature trees.

(d) Trials for the control of capsids by treatment of pods only with a variety of residual insecticides at critical seasons.

(e) Investigations of the possibility of simultaneous control of capsids and *Calonectria* by means of a combined insecticide (DDT) and fungicide (Perenox). Preliminary work is to be performed with seedlings in baskets exposed under young cacao subject to heavy capsid attack. The number of capsid lesions occurring is observed and the number of these which become infected is recorded and the results are related to the spray treatment applied.

(f) Capsid population studies. Critical research on capsids is limited by the lack of reliable sampling methods for the estimation of populations. This problem is to be investigated and, as soon as possible, investigation will be made on the effect of climatic and local environmental factors on capsid abundance.

## 5. EXPERIMENTS ON ESTABLISHMENT AND MAINTENANCE.

(a) Establishment trials. These formal field experiments include several which have been in progress for some years and others about to be initiated. They compare various types of planting material (e.g. bare root plants, basket seedlings and seed at stake), various shade treatments and close planting with subsequent thinning *versus* planting at final spacing. More detailed experiments are in progress and will be commenced to compare the effect of various transplanting techniques on the survival and development of the plants.

(b) Spacing trials. Effect of different spacings on the establishment, growth and yield of Amelonado and Upper Amazon cacaos.

(c) Shade trials and observations. Trials of methods for the renewal of forest canopy in mature cacao ; re-afforestation as a preliminary to cacao re-establishment.

(d) Comparative yield trials of seedlings and rooted cuttings. Selected types of Amelonado, Upper Amazon and Trinitario cacaos will be established as rooted cuttings and as seedlings at varying spacings and their yield and general performance will be observed.

(e) Effect of soil type on pod development and yield : correlation with soil analyses.

(f) Methods of forecasting yields of cacao. The amount of pod setting which occurs at critical times of the year is recorded on a series of sample plots and a relation is sought between this and the final yield of the areas represented by the sample plots.

(g) Study of the effect of retention and removal of chupons on rooted fan cuttings.

## 6. SOIL FERTILITY AND MANURIAL REQUIREMENTS.

(a) Field experiments to determine the effect of various amounts and combinations of major nutrients on (i) the growth and development of newly established Amelonado cacao : (ii) growth and development of young, bearing Upper Amazon cacao ; (iii) yield of fully bearing Amelonado cacao.

(b) Comparison of the effects of different sources of the major nutrients on the growth and yield of newly established and mature Amelonado and Upper Amazon cacaos.

(c) Examination of the effect of nitrogen and phosphate on newly-planted farmers' cacao.

(d) Analysis of profile samples from sites of all the preceding experiments, to be related to the responses obtained.

(e) Examination of the physical and chemical characters of good and bad cacao soils.

(f) Investigation of the means and degree of uptake of major nutrients by analysis of plant organs and by observations of growth rate.

(g) Role of minor elements in cacao nutrition.

## 7. ROOT STUDIES.

(a) Study of the association of fungi with cacao roots. Growth rates of cacao seedlings in sterile and unsterilised soil will be studied together with the reactions of virus-free and virus-infected plants in the presence and absence of root fungi. Isolations will be made of the fungi concerned.

(b) Qualitative and quantitative studies will be made of the distribution of roots of healthy and diseased cacao growing on contrasted soil types. Study of the relation of the distribution of cacao roots to those of shade trees and of possible natural root-grafting will be undertaken. Rate of growth of cacao roots will be studied.

## 8. VEGETATIVE PROPAGATION.

(a) Simplification of established methods of production of rooted cuttings, as an aid to more general adoption of this type of planting material.

(b) Improvement of vegetative propagation methods to facilitate the production of rooted cuttings of " difficult " types and species.

## 9. PLANT BREEDING AND SELECTION.

(a) Progeny and Introductions Trials. Analysis of yield, vigour, bean size, quality and habit of local selections and introduced types, of cacao and their progenies occurring in the experimental areas of the station. Observations will also include studies of susceptibility to attack by pests and diseases. The material studied will also include trees reported by the Departments of Agriculture as of outstanding performance.

(b) Continuation of the breeding programme. The best trees indicated by the observations under (a) above are to be employed as parents for breeding work, having regard to (i) preserving Amelonado quality, (ii) securing high early yield, (iii) securing large bean size and low shell percentage, (iv) producing trees with compact habit of growth (v) securing high fat content.

(c) Comparative growth and yield trials of Amelonado, Trinitario and Upper Amazon types selected under (a) on different soil types and in different climatic zones.

(d) Comparative study of *Herrania* and *Theobroma* species. Especial attention will be paid to (i) resistance to black pod disease, (ii) resistance to cacao viruses, (iii) fat and alkaloid content.

(e) Study of inter-specific crosses. The production, characters and possible economic value of crosses between *T. cacao* and other *Theobroma* and *Herrania* species.

(f) Mechanics of pollination. Investigation of the maximum distance over which cross-pollination occurs; this leads to the determination of the optimum spacing of pollen-supplying trees in plots of self-incompatible cacao. Plots of E1 and of albino cacao will be used as test plants.

(g) Study of incompatibility in cacao. The genetics of incompatibility within Upper Amazon types will be further elucidated. Investigations will be undertaken on the incompatibility systems in Trinitario types, Ecuador selections and in incompatible Gold Coast selections. The cytology and physiological causes of incompatibility will be studied.

(h) Study of the genetics and morphology of hereditary characters of cacao. This involves recognition and detailed study of important characters of the cacao plant. The ultimate aim is to produce chromosome maps as an aid to scientific breeding and its accomplishment will involve work extending over some twenty years.

(i) Production and study of polyploidy with a view to the production of fertile inter-specific hybrids.

(j) Investigation of the possibility of prolonged storage of pollen without loss of viability.

## 10. CACAO FERMENTATION AND QUALITY.

(a) Investigation of the chemical changes occurring during the fermentation of cacao beans. This is performed mainly by small scale fermentation experiments and assessment of the quality of the products. The work has especial reference to the changes affecting polyphenols in the beans, which are believed to be associated with flavour and aroma, and to the various external factors, e.g. pulp sugars, which affect fermentation. Amelonado and Upper Amazon types are considered separately.

(b) A large scale trials to examine the effect on the quality of cocoa of the degree of ripeness at the time of harvest and of storage of pods prior to breaking and fermentation.



(c) Investigation of the changes in "purple" bean content of cured cocoa during storage.

(d) A survey of fermentation methods employed by cacao farmers.

(e) A study of methods for the evaluation of cocoa quality by taste panels.

(f) Study of the factors affecting variation in content of cocoa fat and alkaloids in cured cocoa (especially seasonal and climatic factors).

#### 11. PIN-HOLE BORER INVESTIGATIONS.

Study of the factors predisposing to borer attack ; insect species involved ; economic role of the insects ; methods of control.

#### 12. INSECTICIDE STUDIES.

(a) Effect of insecticides on fruit setting and yield. In order to ensure that measures for the control of pests of cacao shall not be such as will deplete the population of pollinating insects, experiments and observations will continue on the setting and yield of pods in areas intensively treated with insecticides and fungicides. Laboratory experiments will also be conducted to test the effect of insecticides and fungicides on pollen germination and pollen tube growth.

(b) Systemic insecticides. Joint experiments with Messrs. Pest Control Limited will be continued to investigate the relative efficiency and costs of different methods for the application of Hanane, the effect of Hanane and its components on the tree and on the flavour and quality of the crop produced by treated trees. From recent experience it appears unlikely that systemic insecticides can be applied economically to cacao, unless some major development occurs leading to the use of entirely new products or different methods of application. It is important, however, that no possible developments should be overlooked and screening trials will continue on all such preparations as become available for the possible control of mealybugs and capsids, both of which will be used as test insects in the trials.

#### 13. ARBORICIDES.

A comprehensive selection of chemicals has been applied to cacao and to forest trees for trial of their arboricidal effects. The final effects of certain poisons on some of the experimental trees still remain to be observed, but it is expected that these experiments will be brought to a conclusion during the year.

#### 14. INVESTIGATIONS ON CHERELLE WILT.

The effects of nutrition, seasonal and environmental conditions and hormone activity on cherelle wilt will be studied. This will lead to investigation of the effect of hormone sprays on survival of cherelles and pods.





